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This publication contains descriptions of space science activities that can be conducted with simple equipment. There are activities suitable for both elementary and secondary school children. Activities are placed under the headings: Astronomy, Atmosphere, Universal Gravitation, Aerodynamics, Guidance and Propulsion, Tracking and Communications, Thermal Conditions, Radiation, Analysis of Extraterrestrial Materials, Extraterrestrial Life, Man's Vital Functions in Space, Life Support Systems, and Physiological and Psychological Aspects of Space Flight. Historical and background information as well as illustrative diagrams accompany the suggested activities. (BR)

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EXPERIENCES IN

SPACE SCIENCE

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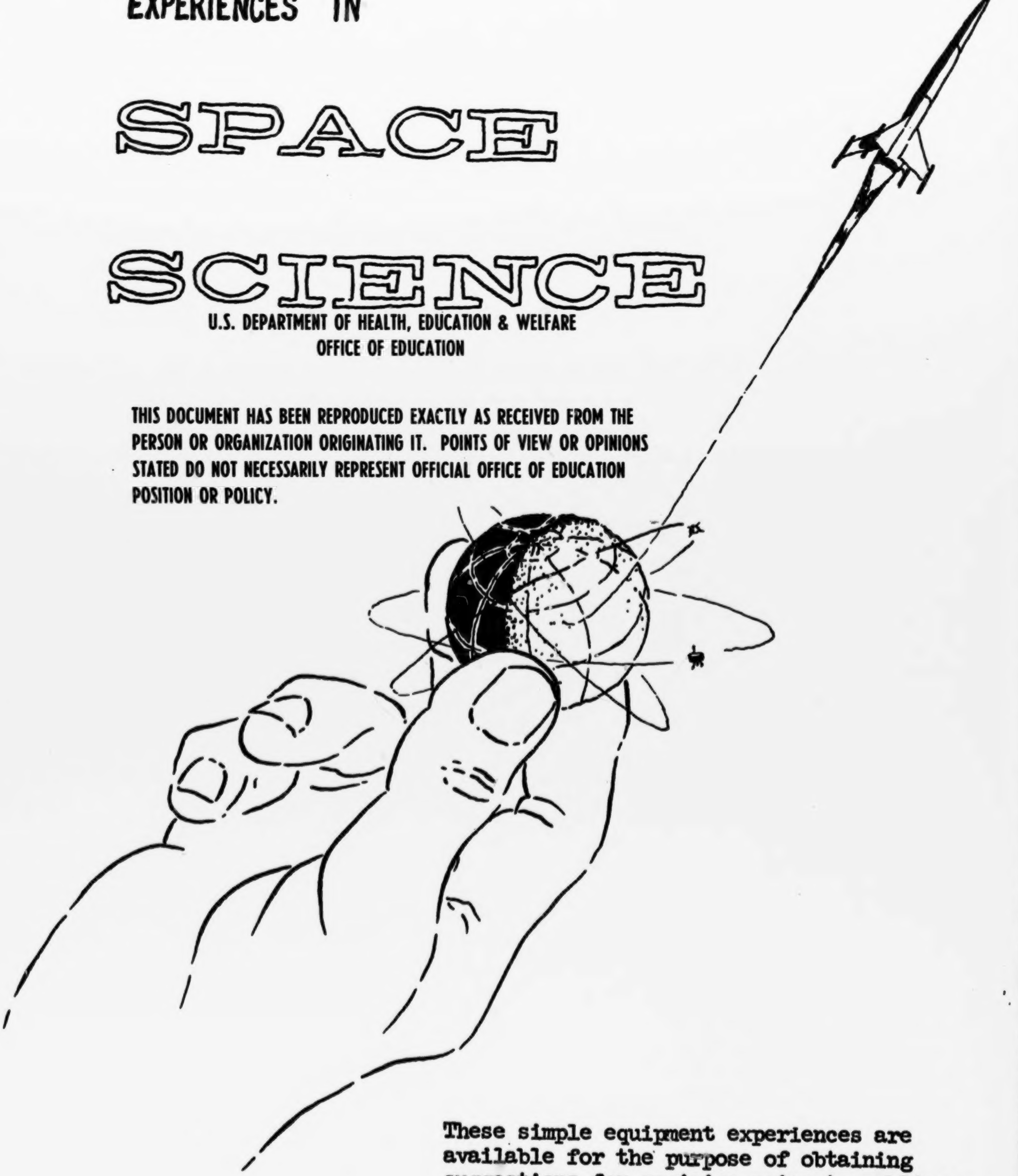

These simple equipment experiences are available for the purpose of obtaining suggestions for revision prior to publication. Please send your suggestions and criticisms to Educational Programs Division, FE, NASA, Washington, D. C. 20546.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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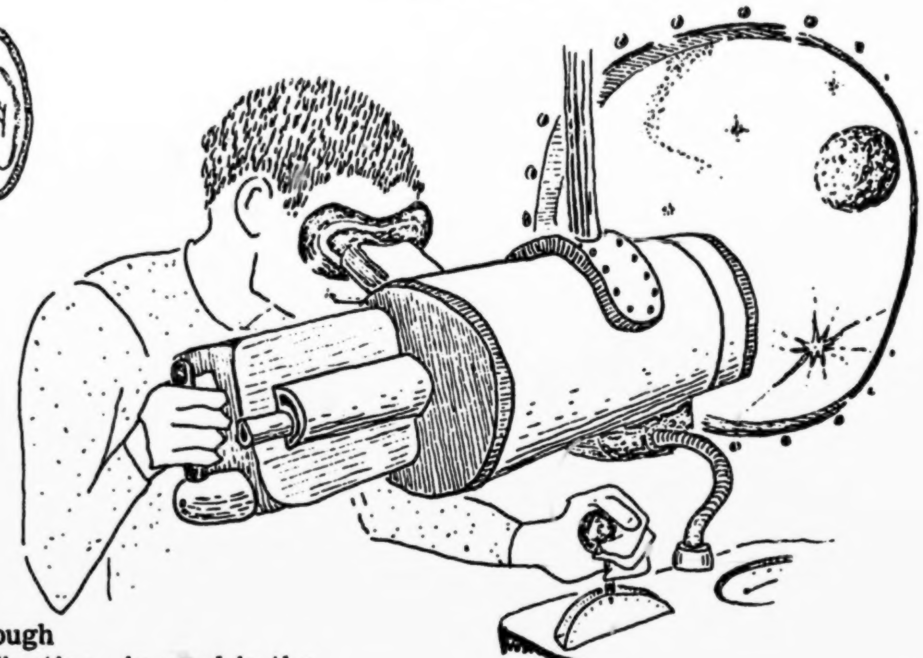
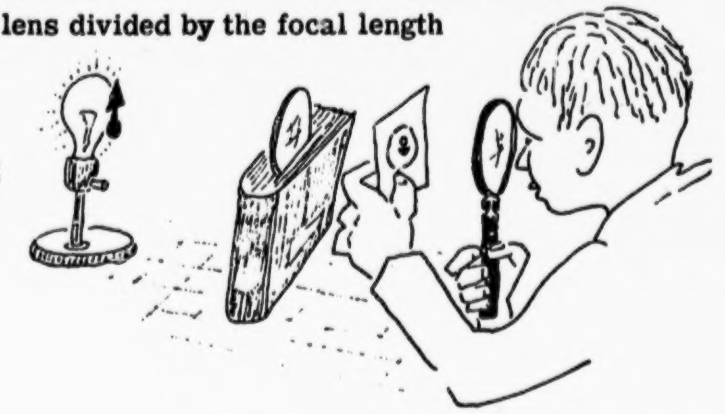
REFRACTING TELESCOPE



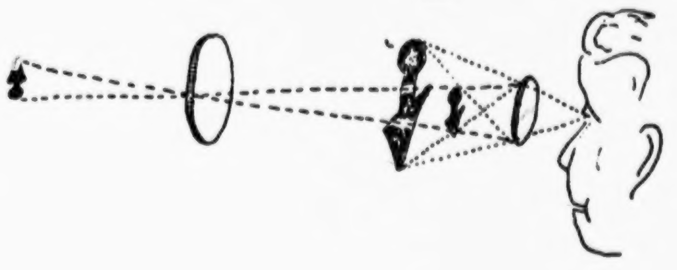
The principle of refraction, i.e., the bending of light rays through lenses to produce magnification, is used in the construction of today's refracting telescopes. One common type of refracting telescope was developed about 1610 by Galileo, the famous Italian scientist, and hence is also known as the Galilean telescope.

In a refracting telescope, a long-focus, or objective, lens acts in two ways: it bends light waves until they come to a point, known as the focal point, and at the same time it inverts the image. The light concentrated in the focal point, carrying the image, then passes on through an eyepiece lens, which enlarges or magnifies the image, making the distant object seem much nearer than it is.

The model at the top left is simple to construct and gives a crisp, clear field at 3 1/2 power. This means a magnification of 3 1/2 times. The telescope's magnifying power will equal the focal length of the objective lens divided by the focal length of the eyepiece lens.



In the illustration at the right, an inverted image is seen on a "screen" of wax paper with the aid of a magnifying glass. In a real telescope, of course, there is no screen.



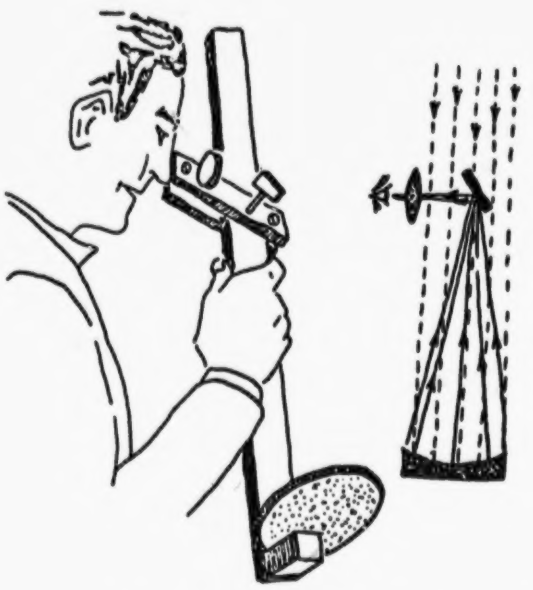
Reference: Edmund Scientific Co. Astronomy and You. Barrington, N. Y. : Edmund Scientific Co., 1960.

THE BIG EYE - AN ORBITING ASTRONOMICAL OBSERVATORY -

Astronomers have been trying to peer through the earth's hazy, moving atmosphere into the universe ever since the beginning of time. But this ocean of air absorbs, weakens, and scatters the very radiations which are particularly useful in imparting knowledge of the universe. In more recent times, observatories built atop mountains and instruments designed to detect very faint emissions have aided in the gathering of data. The observers, however, continue blocked by a variety of factors. Ultraviolet rays, for instance, cannot penetrate the atmosphere because of atmospheric ozone; the infrared are absorbed by water vapor and carbon dioxide; and x-rays, gamma radiations, and cosmic radiations are altered before they can even reach the earth-bound instruments.

A simple parabolic mirror used as a light gatherer on an observatory in space, however, would bring in more data in a short time than has been accumulated thus far from earth. (A fuller understanding of the stars, for instance, would be one result.) By using a system of attitude controls, this instrument could be directed at any point in space for almost any length of time as it orbited the earth. The data, recorded on video-tape, could be transmitted by small television cameras to stations on the earth's surface for analysis.

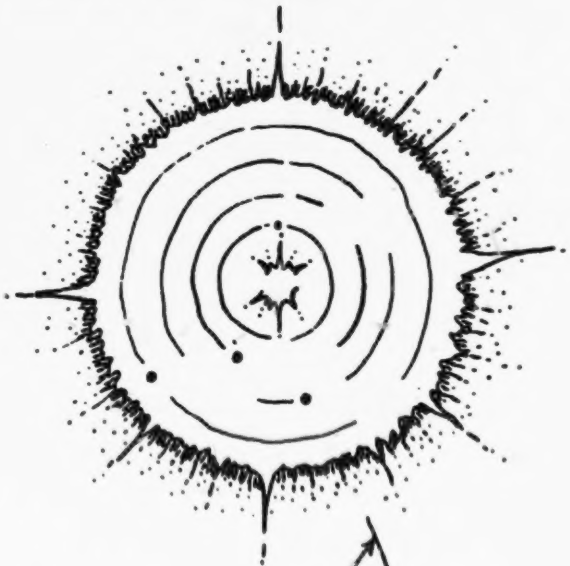
Arrange a concave mirror such as a shaving mirror, a small flat mirror, and a short-focus magnifying glass as illustrated. For viewing distant objects, the eyepiece, as represented by the magnifying glass, should be near the principal focus of the concave mirror; the eyepiece acts to enlarge the image produced by concave mirror. The small flat mirror is used to direct the image to the eyepiece. Any distortion of the image will be due to the imperfect surface of the concave mirror. (Note: Astronomical mirrors are ground to a parabolic curve rather than the spherical curve of ordinary concave mirrors.)



Reference: Hoyle, Fred. Frontiers of Astronomy. New York: Mentor, 1963.

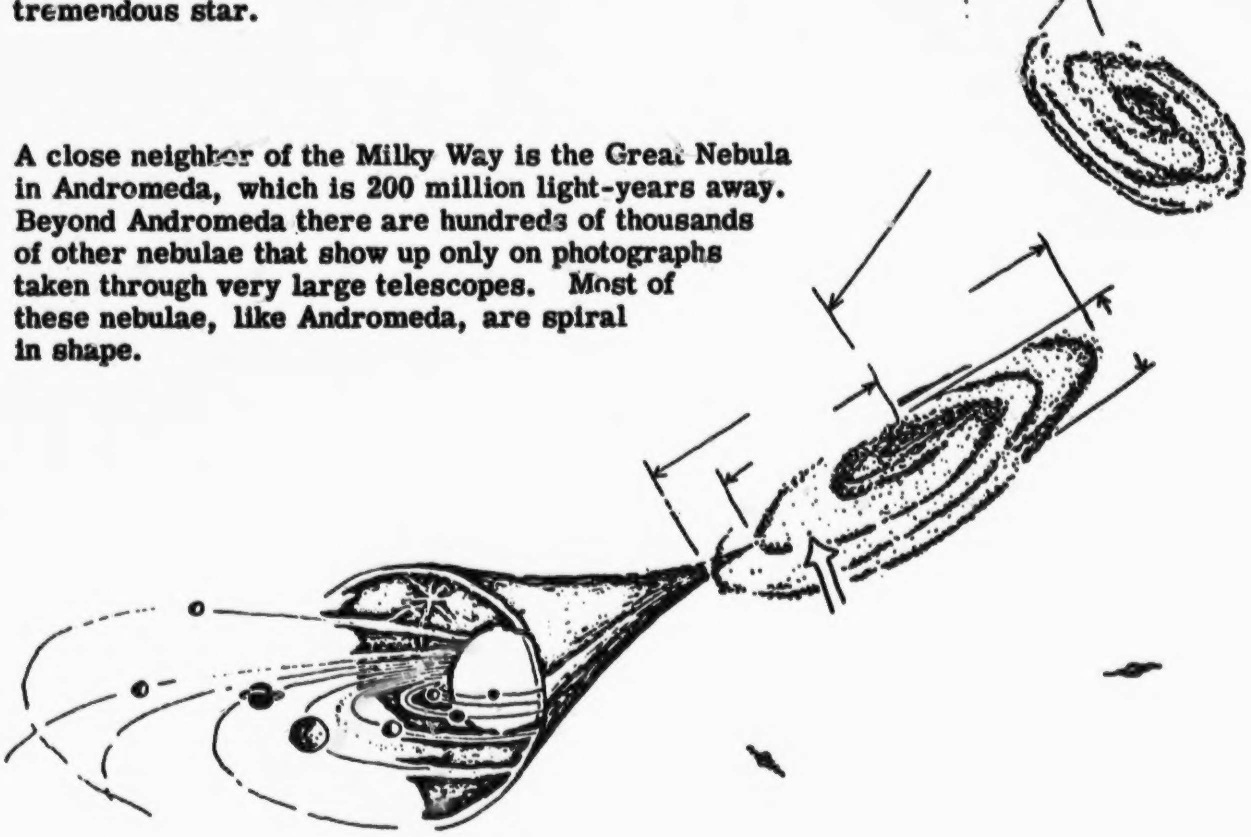
THE NIGHT SKY

When we look up into a clear, night sky, we are aware of countless objects, extending farther than we can see into the distance. With the naked eye, most of these objects are seen only as tiny dots of light. But with a pair of binoculars or an inexpensive telescope, and particularly with professional astronomical instruments such as the large optical or radio telescopes and special cameras, the dots in the sky take on recognizable forms. They are the stars of our own galaxy, the Milky Way; and beyond them thousands upon thousands of nebulae stretching away in all directions in the great vastness of outer space we know as the universe.



To get some idea of the vastness of the universe, look up into the sky on a clear, summer evening and observe the star Antares, the bright red star in the constellation Scorpides. Antares is 250 light-years away. It is one of the largest stars known—about 280 million miles in diameter. Our own solar system, radiating out beyond the orbit of Mars, would fit inside this tremendous star.

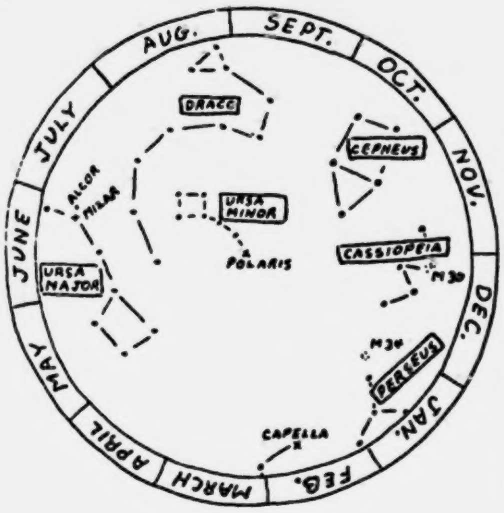
A close neighbor of the Milky Way is the Great Nebula in Andromeda, which is 200 million light-years away. Beyond Andromeda there are hundreds of thousands of other nebulae that show up only on photographs taken through very large telescopes. Most of these nebulae, like Andromeda, are spiral in shape.



Reference: Coombs, Charles. Gateway to Space. New York: Morrow, 1960.

This star guide is designed to be glued to the outside of a No. 303 tin can. The major constellations are shown with navigational stars, star clusters of particular interest, and nebulae. All are visible to the naked eye on clear, moonless nights. The use of binoculars or a small telescope will clarify the detail of a specific area.

Hold the star guide overhead, with the current month in a readable position. Compare the star patterns on the guide with those of the brighter star groups in the sky.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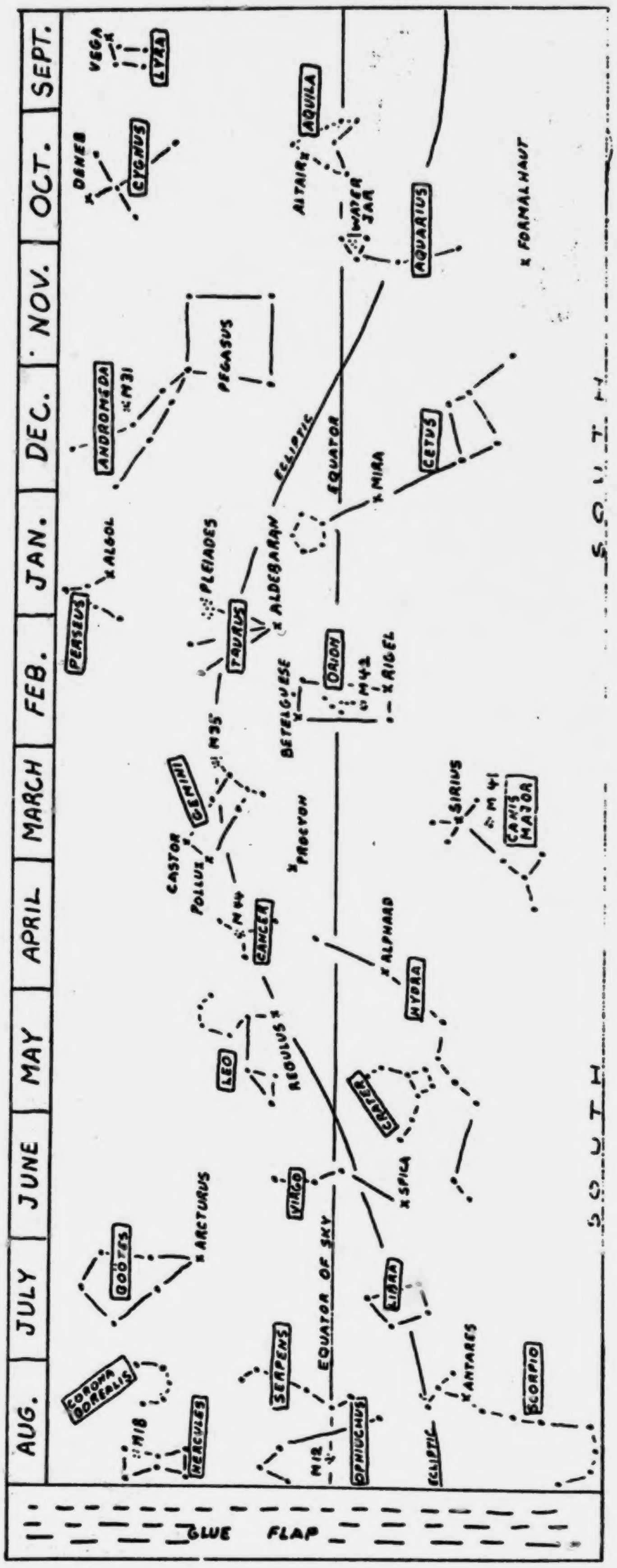
CAPELLA

A GUIDE TO THE STARS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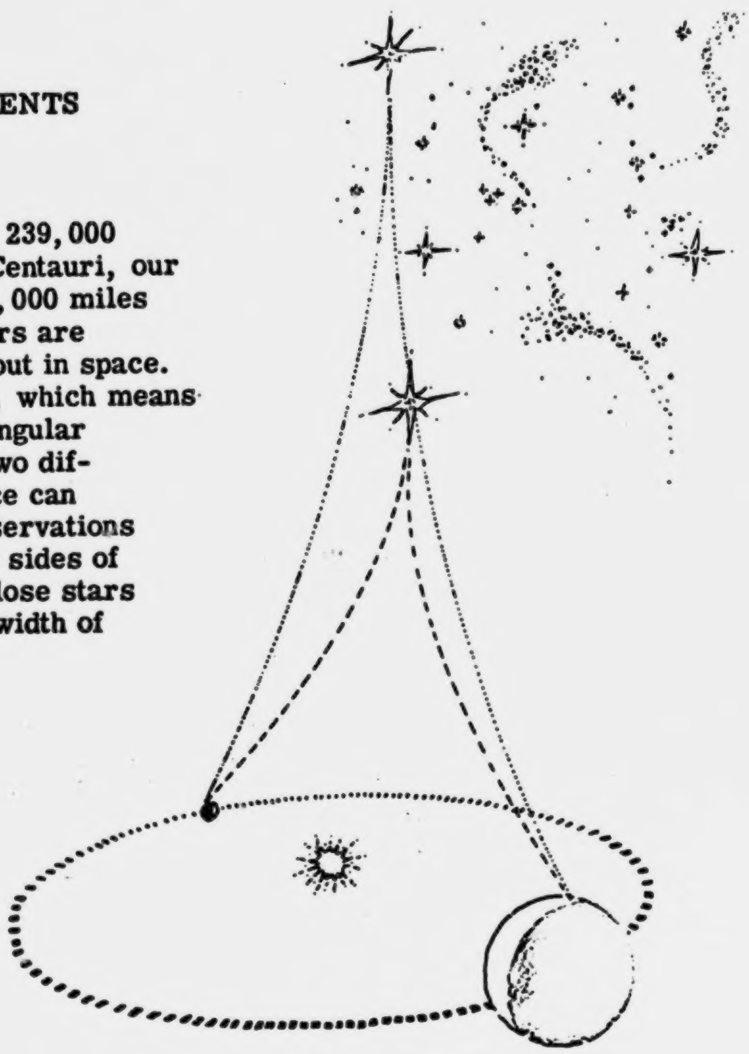
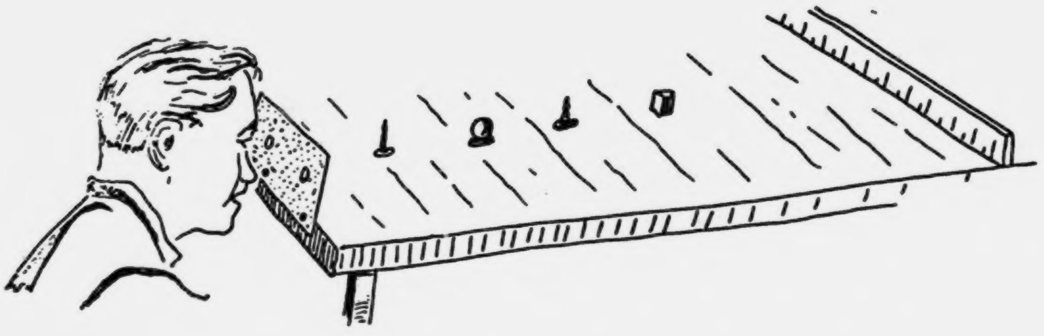
FORMALHAUT
ANDROMEDA
M31
PEGASUS
ECLIPTIC
EQUATOR
MIRA
CETUS
ALGOL
PERSEUS
PLEIADES
TAURUS
ALDEBARAN
ORION
M42
RIGEL
BETELGUESE
M35
GEMINI
CASTOR
POLLUX
PROCYON
SIRIUS
M41
CANIS MAJOR
M44
CANCER
ALPHARD
HYDRA
LEO
REGULUS
CRATER
VIRGO
SPICA
ARCTURUS
BOOTES
CORONA BOREALIS
EQUATOR OF SKY
LIBRA
SERPENS
ANTARES
SCORPIO
M13
HERCULES
M12
OPHIUCHUS
ECLIPTIC
SOUTH
GLUE FLAP

ASTRONOMICAL MEASUREMENTS

When you read that the moon is about 239,000 miles from the earth and that Alpha Centauri, our nearest neighbor star, is 25,600,000,000 miles away you may wonder how astronomers are able to measure such vast distances out in space. The answer is that they use parallax, which means the apparent difference between the angular directions of an object viewed from two different locations. The moon's distance can be calculated, for instance, from observations made at the same time from opposite sides of the earth. The distance to various close stars can be measured by using the entire width of the earth's orbit.

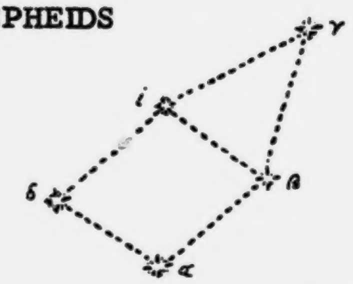


Set a yardstick across one end of a table and tack a file card, with two holes punched in it, to the other end. Place wood screws five, ten, fifteen, and twenty inches from the card. Sight through one hole in the card and then through the other. Record the position of the screws as indicated by the yardstick readings. Note how the readings are related to each other.



Reference: Adler, Irving. The Stars. New York: Signet, 1962.

TAPE MEASURE OF THE UNIVERSE: THE CEPHEIDS



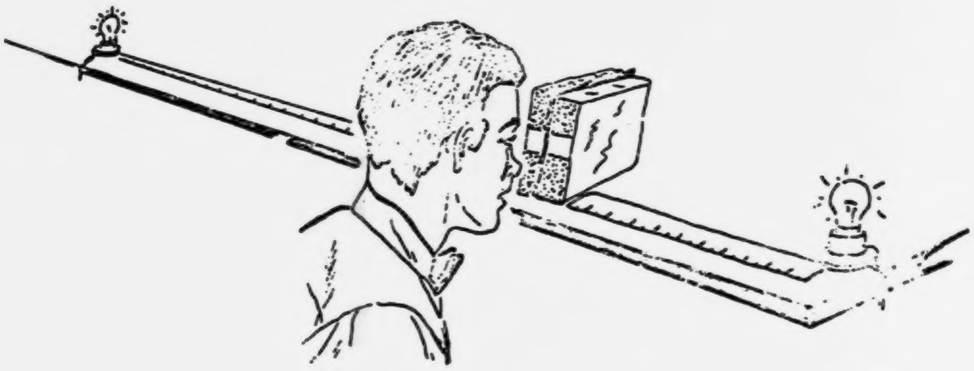
In the constellation Cepheus, near Polaris, the North Star, there is an especially interesting star. It is Delta Cephei, the variable star which grows brighter and dimmer with a regular rhythm about every five and a half days.

Astronomers call all pulsating stars Cepheids because Delta Cephei was the first to be described in detail.

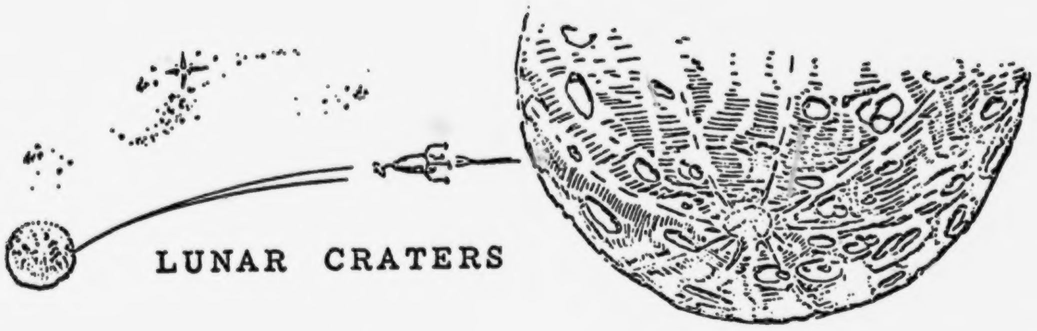
In the Southern Hemisphere, the Magellanic Clouds have many Cepheid blinking stars. By comparing photographs taken at different times, astronomers have found that the brighter Cepheids take a longer time to blink than do the dimmer ones; and by applying the known rule that light diminishes with the square of its distance, the astronomers were then able to determine the distance of many remote stars. First, they measured the number of days in the period of the star. Then, they determined how bright it should be compared to our sun. From this finding, they figured out how far away it must be to appear as dim as it does.

The light year is used as the unit of measurement of the great distances of the universe. Since light travels at approximately 186,000 miles per second, one light year is 186,000 x 60 x 60 x 24 x 365 miles in length. The nearest star, other than our sun, is Alpha Centauri, about 4 1/2 light years away. Sirius is about 8 1/2 light years distant, the Magellanic Clouds about 150,000 light years, and the Great Nebula in Andromeda about two million light years away.

The luminous intensity of any light can be compared with any other illuminations with an instrument called a photometer. Warm the faces of two identical blocks of paraffine and with a piece of aluminum foil between them press them together, like a sandwich. Place this block so that its flat surfaces will face the two sources of light to be compared. Look at the edges of the block and compare the brightness of each square of paraffine. Two similar light bulbs placed on equal distance on each side will illuminate the sides of the block equally. When one source of light is removed to twice the distance of the other, its light intensity will have to be considerably increased to equal the other.



Reference: Young, Louise B., editor. Exploring the Universe. New York: McGraw-Hill, 1963.



LUNAR CRATERS

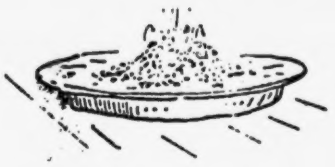
The surface of the moon was described by Galileo in 1629, more than 300 years ago. Very little has happened either to the lunar surface or the techniques used to observe it since that time and, with a few exceptions, Galileo's description is still valid today.

But observation alone cannot answer all the questions concerning the moon and the history of its formation. The origin of the moon's craters, for instance, remains a mystery and is the subject of opposing theories. Many astronomers believe that the craters were caused by volcanic eruption, that is by a geological or selenological process. Many geologists, on the other hand, explain the craters by saying they were caused by the impact of bodies falling on the moon, that is, by an astronomical process.

Spacecraft missions designed to fly close to the moon's surface for direct observation or to soft land will probably solve this mystery and may even fill in some of the gaps in our knowledge of the history of the solar system.

SELENOLOGICAL THEORY

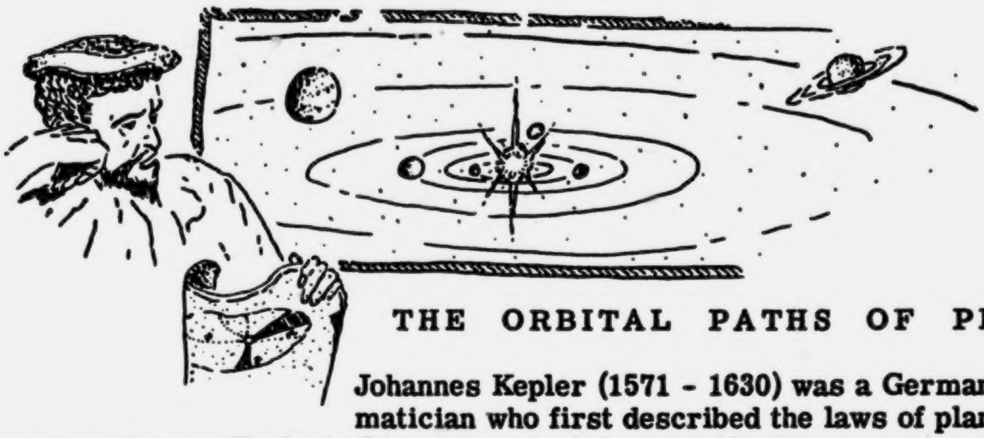
Fill a large paper plate or other shallow container with plaster of Paris. In the center make a depression about the size of a bottle cap. When the plaster of Paris is dry, fill the depression with crystal ammonium bichromate and light the chemical with a match. This will result in an eruption. Notice that as each crystal erupts, it will produce an ash which is many times its original volume. The ash is deposited on the sides of the heaped up chemical and thus form a cone characteristic of volcanic mountains.



ASTRONOMICAL THEORY

Mix a little ink or water paint in soft plaster of Paris and make a number of colored balls about the size of peas. When the balls are hard, drop them into a plate of soft, white plaster of Paris, about the consistency of heavy cream, as it is in the process of hardening. (Note: A pinch of salt will hasten the hardening process.) When the plaster of Paris in the plate is hard, carefully cut through some of the mineature meteors and their craters with a fine-toothed coping saw. The characteristic shape of a moon crater, with its surrounding cone-like wall, can usually be observed.

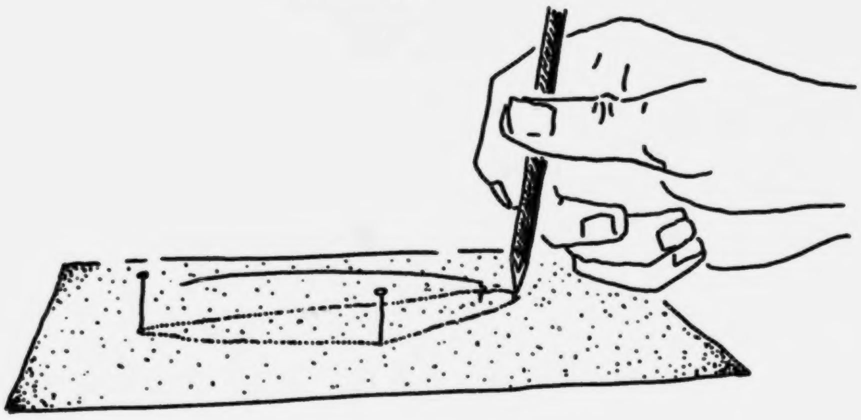
Reference: Branley, Franklyn M. The Moon: Earth's Natural Satellite. New York: Macmillan, 1960.



THE ORBITAL PATHS OF PLANETS

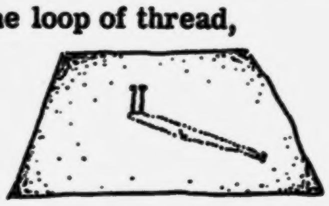
Johannes Kepler (1571 - 1630) was a German mathematician who first described the laws of planetary motion. Known since then as Kepler's Laws, they include the following precepts: The orbits of all planets around a sun are elliptical, with the main body lying at the principal focus of the ellipse. The square of the orbital period of a satellite is proportional to the cube of its relative distance from the principal focus.

Example: **An object 1 1/2 astronomical units (an astronomical unit is the distance between the earth and the sun) average distance from the sun would take 1.84 years to make one orbit.**



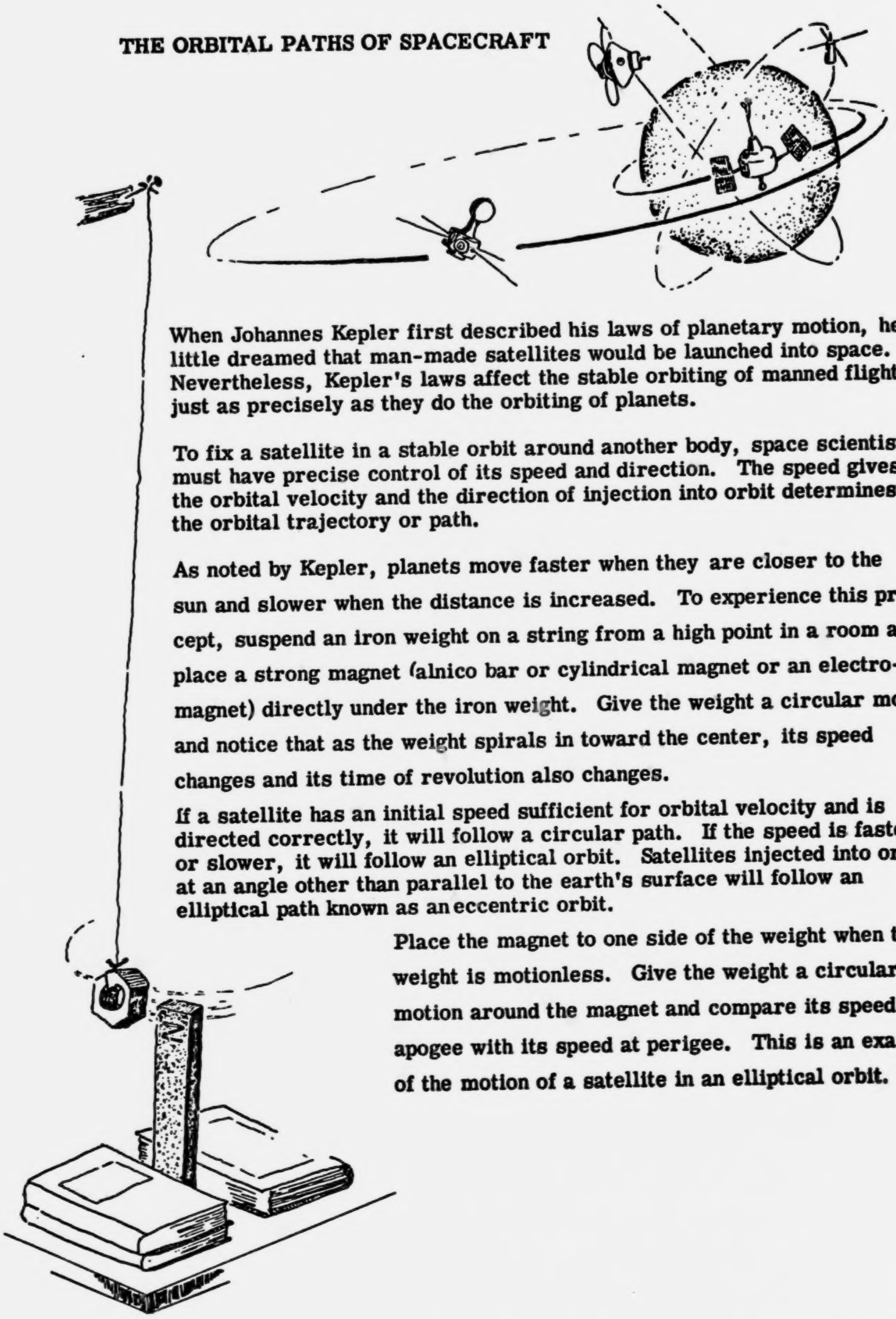
To draw an ellipse, first stick two pins about two inches apart near the center of a sheet of paper. Using a 12-inch piece of thread, make a loop and place it over the pins. Place the point of a pencil inside the loop and, with the thread as a guide, draw a line. The finished figure is an ellipse.

To show the shape of the earth's orbit around the sun, place the pins one-eighth of an inch apart near the center of the paper. Using the same loop of thread, draw a line in the same way as before. Notice how much the figure this time looks like a circle.



Reference: Armitage, Angus. The World of Copernicus, New York: Mentor, 1954.

THE ORBITAL PATHS OF SPACECRAFT



When Johannes Kepler first described his laws of planetary motion, he little dreamed that man-made satellites would be launched into space. Nevertheless, Kepler's laws affect the stable orbiting of manned flight just as precisely as they do the orbiting of planets.

To fix a satellite in a stable orbit around another body, space scientists must have precise control of its speed and direction. The speed gives the orbital velocity and the direction of injection into orbit determines the orbital trajectory or path.

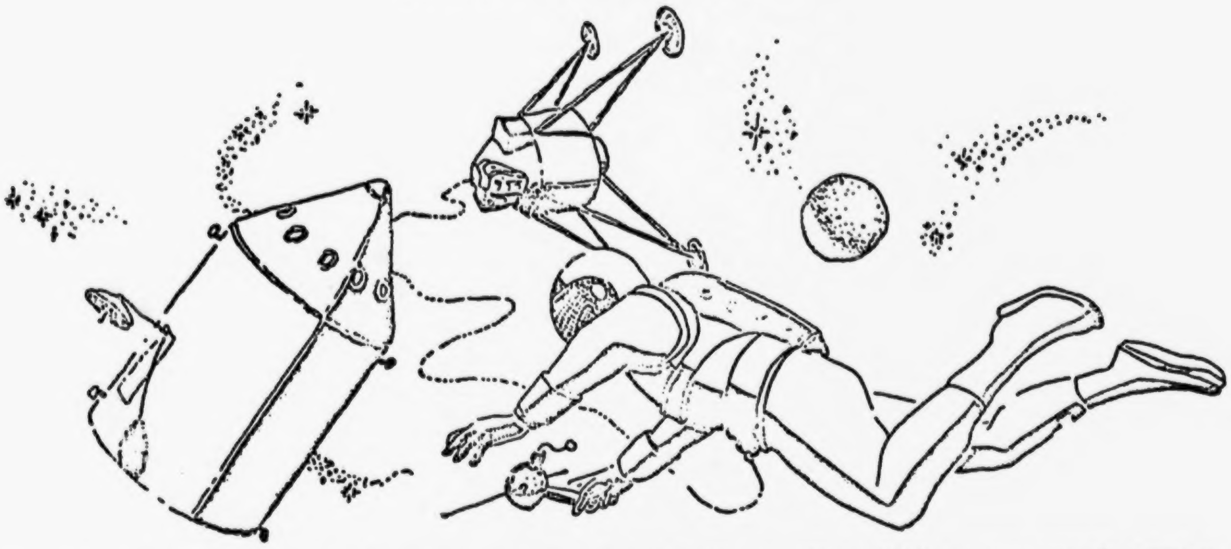
As noted by Kepler, planets move faster when they are closer to the sun and slower when the distance is increased. To experience this precept, suspend an iron weight on a string from a high point in a room and place a strong magnet (alnico bar or cylindrical magnet or an electromagnet) directly under the iron weight. Give the weight a circular motion and notice that as the weight spirals in toward the center, its speed changes and its time of revolution also changes.

If a satellite has an initial speed sufficient for orbital velocity and is directed correctly, it will follow a circular path. If the speed is faster or slower, it will follow an elliptical orbit. Satellites injected into orbit at an angle other than parallel to the earth's surface will follow an elliptical path known as an eccentric orbit.

Place the magnet to one side of the weight when the weight is motionless. Give the weight a circular motion around the magnet and compare its speed at apogee with its speed at perigee. This is an example of the motion of a satellite in an elliptical orbit.

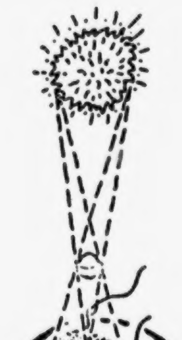
Reference: General Dynamics Corp., Convair Division. Space Primer: An Introduction to Astronautics. San Diego: General Dynamics Corp., 1960.

SPACE SHADOWS



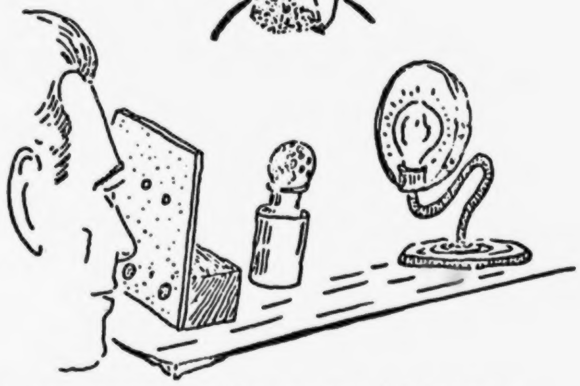
Astronauts able to leave their spacecraft in protective suits will be very much aware of the deep blackness of shadows and the apparent, unusual shape of objects. Both phenomena result from the lack of air molecules to scatter light and radiant energy from the sun.

The conditions in which a shadow falls on an observer or an object in space is called an eclipse. Eclipses of the sun and moon are caused by unique, natural conditions. In the first place, the sun and the moon viewed from the earth seem to be the same size; both apparently occupy about one-half degree angle, or about the size of a ten-cent piece held five feet away.



A solar eclipse occurs at the time of a new moon, when the sun, moon, and earth are in a direct line, with the moon between the sun and the earth. During a total eclipse, an observer on earth sees the entire disc of the sun briefly blotted out.

A lunar eclipse occurs at the time of the full moon, when the earth comes between the moon and the sun. The earth's shadow is about 6000 miles in diameter at the point where the moon passes through it and the eclipse can, therefore, last for hours. But because the sunlight is bent by refraction of the earth's atmosphere and strikes the moon's surface, the moon is partially visible during the entire lunar eclipse.

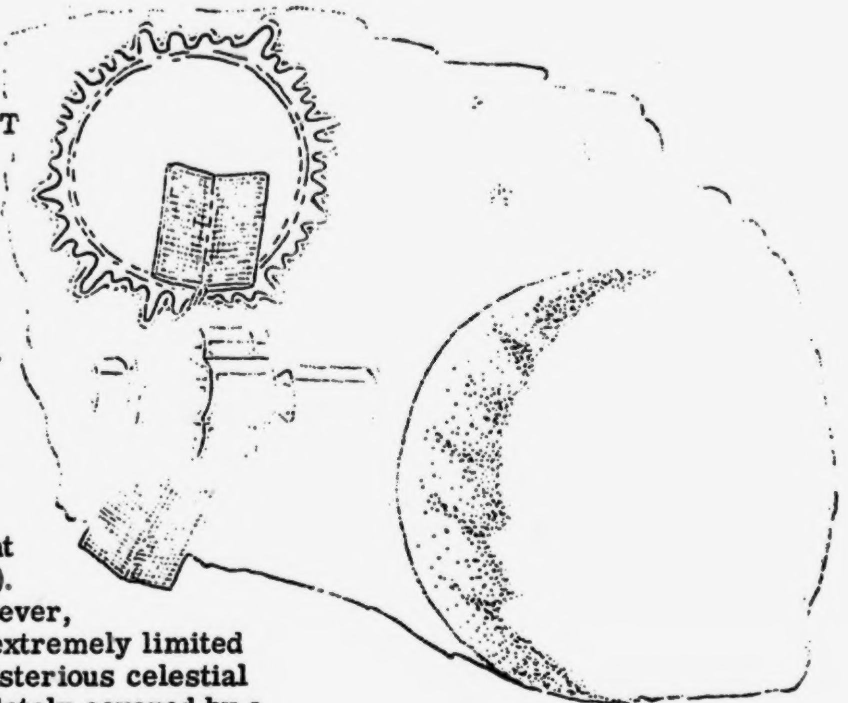


To see a miniature eclipse, place a small ball, representing the moon, between a bright lamp bulb and a piece of paper, representing the earth. Move the ball until its shadow is dark in the center and surrounded by a lighter ring. Punch a hole in the paper at a point which corresponds to the center of the dark area; punch another hole at a point corresponding somewhere in the surrounding ring. Look through these holes and note the relative positions of the ball and lamp bulb.

Reference: Maloney, Terry. The Sky is our Window. New York: Sterling, 1930.

THE MYSTERIOUS PLANET

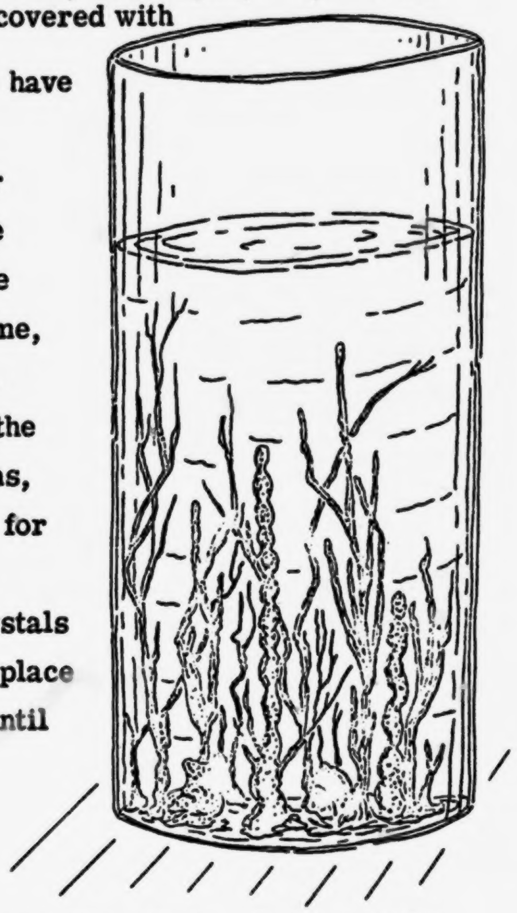
- VENUS -



The Earth's closest planetary neighbor is Venus. Traveling as close as 26 million miles, Venus is considered our sister planet because it is roughly the Earth's size and has about the same mass (amount of matter in its composition). Beyond these few facts, however, information about Venus is extremely limited and the planet remains a mysterious celestial body whose surface is completely covered by a thick layer of clouds.

Scientists are continually trying, therefore, to gather additional data on Venus. In this task, they use radar reflections, infrared measurements, and spectrographic observations. Spacecraft carrying sensitive instrumentation on fly-by missions are also being used, as will be vehicles equipped with landing robot-package equipment. These space-age detection devices, it is hoped, may inform us as to whether Venus, the planet of mystery, is covered with waterless deserts of drifting sand, jungles of lush, tropical plant life, or some terrain which we have never imagined.

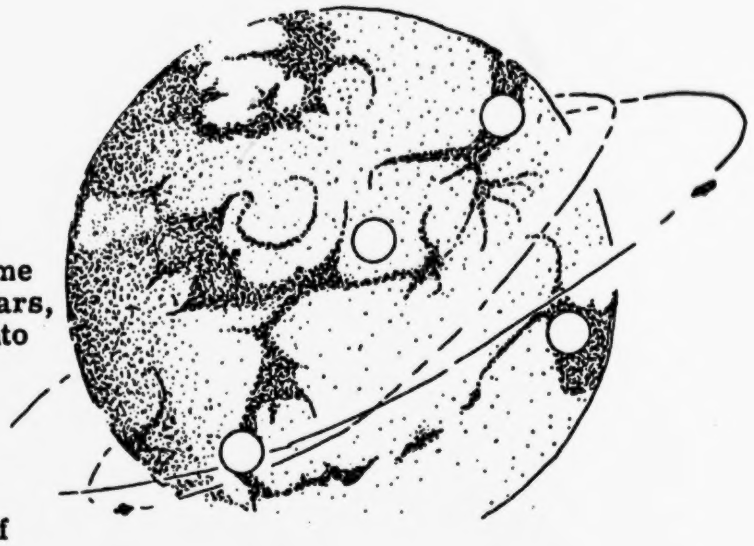
A crystal jungle, which might not be too dissimilar in appearance from the landscape on Venus, can be developed in a transparent jar of any size. Fill the jar with a 25% water-glass solution, i.e., by volume, one part of sodium silicate to three parts of water. Drop into the liquid a few small crystals of any of the following salts: copper sulphate for blue formations, iron chloride for orange, potassium permanganate for purple, nickel sulphate for green, cobalt chloride for pink, and lead acetate for white. When the crystals stop growing, carefully siphon off the liquid and replace it with a clean gelatin solution. Allow this to set until the gelatin is firm.



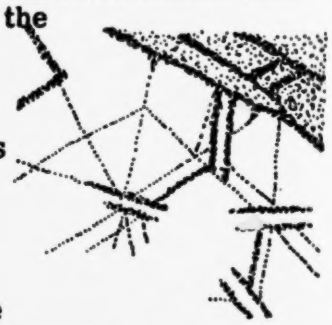
Reference: Maloney, Terry. Other Worlds in Space. New York: Sterling, 1957.

THE RED PLANET

- MARS -

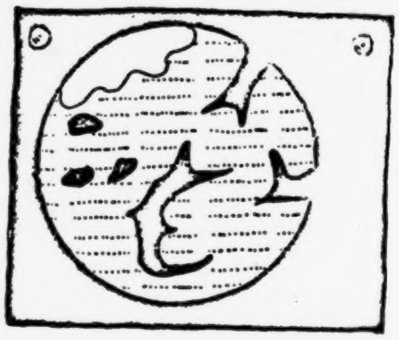


An important objective of manned space flight is the exploration of some of earth's neighbors. The planet Mars, which every 15 to 17 years swings into its closest proximity to the earth, i.e., 35 million miles away, has been most seriously considered in this connection because of characteristics which are more nearly earth-like than those of the other planets.



Mars has been under observation for more than 400 years. Its environment was once described as being like "the Sahara desert removed to the South Pole." It is bright yellowish-red in color, with patches of brilliant white marking both its north and south polar regions. Its southern hemisphere offers the most prominent surface features. The Thoth-Nepenthes (1) and the Pandorae Fretum (2) show changes at various seasons. The Solis Lacus (3) and the Mare Acidalium (4) also change in both shape and intensity.

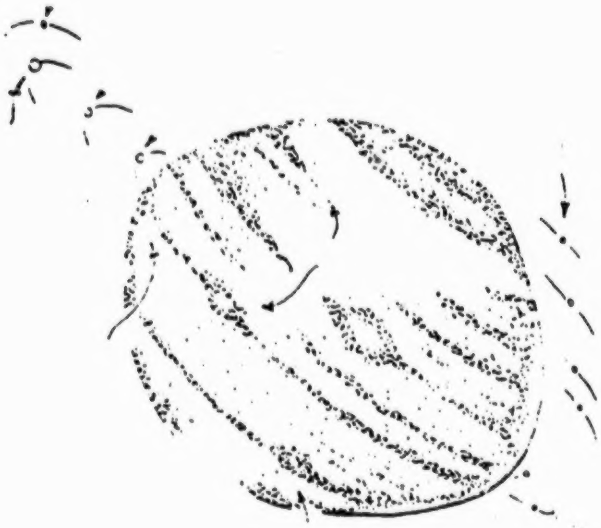
In 1877 Schiaparelli, the Italian astronomer, discovered the so-called canals. In the early 1900's, Percival Lowell, the American astronomer and mathematician, concluded that the canals were evidence of a developed form of life by beings of considerable intelligence. Today, some astronomers believe that the fine, regular network of Schiaparelli's canals is only an optical illusion; others believe the canals are natural features, such as rivers. Supporting the latter viewpoint is the fact that these areas undergo seasonal changes, especially in color. The changes are attributed either to vegetation—which dies down during the dry, bitterly cold Martian winter and comes to life, with minimum moisture, in the spring—or to lifeless, and deceptive, chemical compounds.



For a simulated telescopic view of Mars, cut a four-inch circle from a piece of newspaper. As shown in the illustration at the right, paste it against a background of black paper, add a white polar cap, and indicate a few of the principal Martian seas and lakes with black ink or black paper cut-outs. Hang the result on a wall and stand four feet away, viewing it with half-closed eyes. Notice how grey, connecting lines seem to shoot between the lakes and the points of the central sea. The lines will not be equally distinct but they will suggest the canals described by Schiaparelli and Lowell.

Reference: Levitt, I. M. A Space Traveler's Guide to Mars. New York: Holt, 1958.

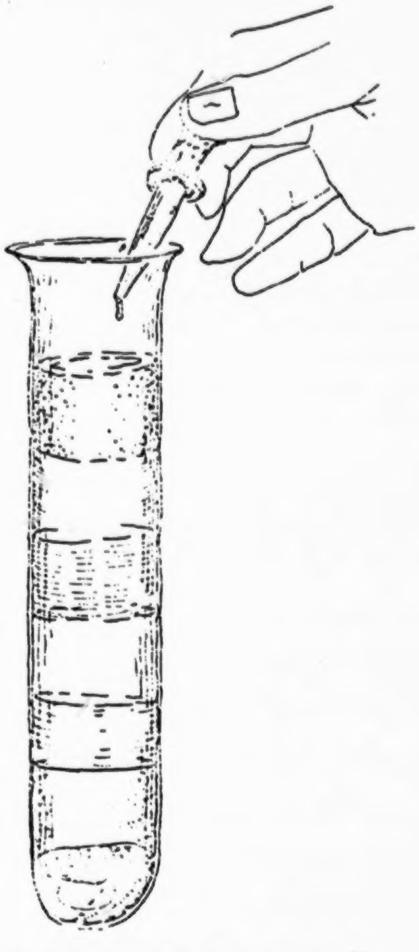
THE GIANT PLANET - JUPITER -



The planets of the solar system can be divided into two groups: the terrestrial planets, Mercury, Venus, Earth, and Mars; and the major planets, Jupiter, Saturn, Uranus, and Neptune. Unlike the terrestrial planets, about whose composition estimates can be made because they are all somewhat like the Earth, the larger planets remain mysterious because they are enveloped in huge atmospheres, thousands of miles deep.

The nearest of all the major planets, Jupiter, has been the one most studied. Covered by a Joseph's coat of many colors, Jupiter is striped with alternate bands of various shades of yellow, brown, and orange and marked with the Great Red Spot, a fairly constant splotch which changes periodically in color and size. At irregular intervals, Jupiter is also patched with olive green and blue markings.

The many colors suggest the theory that Jupiter's atmosphere, called the Jovian atmosphere, surrounds a relatively small core of rock and metal (the planet's weight is only a little heavier than an equal amount of water with a specific gravity of 1.3); and that the atmosphere, itself, is composed of several layers. The innermost part of the atmosphere seems to be made up of a thick layer of ice, under frozen ammonia, which, in turn, is covered by a sea of liquid methane and, finally, by an outer layer of hydrogen, helium, and vapors of ammonia and methane. Due to the Coriolis effect, i.e., atmospheric movement due to rotation, the various atmospheric layers are exposed at various times, resulting in the changes in color and pattern.



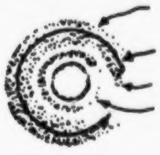
To show how differences in density allow substances to rest, one on top of the other, without visibly mixing, construct a "Jacob's tube." Place a drop of mercury in the bottom of a test tube or tall, narrow jar. Add a strong salt solution dyed pink with vegetable dye and, using a medicine dropper or soda straw, carefully float a strong copper sulphate solution on top. Next, add a little clear water, which will float. Then, in order, add castor or olive oil, light machine oil, and, finally, gasoline. Observe the effect when a small amount of rubbing alcohol, colored with dye, is poured on the gasoline.

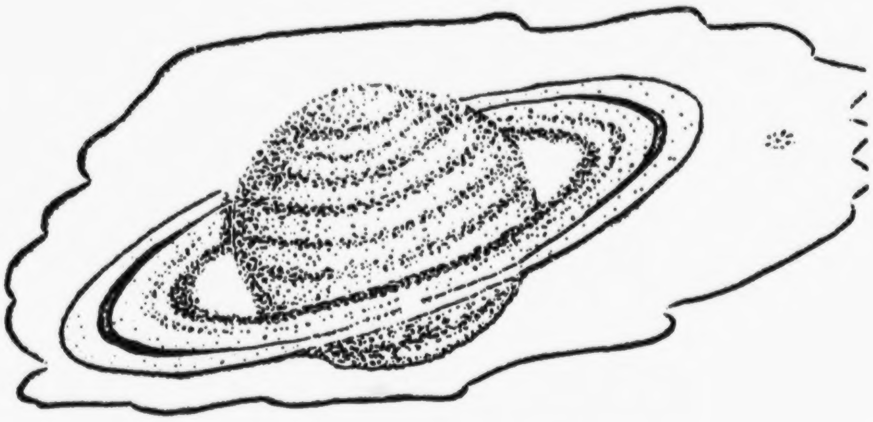
CAUTION: DISPOSE OF THE LIQUIDS CAREFULLY BY POURING THEM INTO A HOLE IN THE GROUND AND COVERING WITH SOIL.

Reference: Opik, Ernst J. The Oscillating Universe. New York: Mentor, 1960.

THE RINGED PLANET

- SATURN -

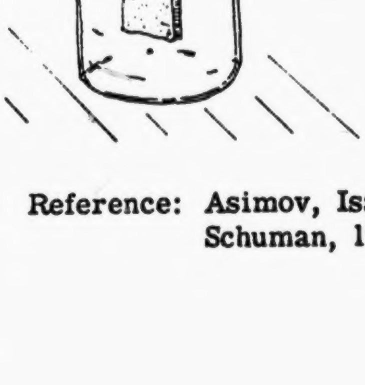




Saturn, second largest planet in the solar system, has far less mass than its smaller neighbors. Made up of particularly light material, it is only 12% as dense as the earth and actually less dense than water. It is the center of its own planetary system and has nine known satellites, one of which, Titan, is almost as large as Mars and the only satellite which shows positive evidence of an atmosphere. Saturn's speed of rotation is variable, with its equatorial regions rotating faster than its polar regions. The flattening at its poles (more than 10%) is quite noticeable. Because of a surface temperature of about 240 below zero, it is assumed that most of Saturn's atmosphere is frozen in the form of crystals.

The Dutch astronomer, Christian Huygens, in 1656 pointed out that Saturn had what he thought was a single, large, flat ring around it. Since then, we have discovered that Huygen's large flat ring—among the most beautiful sights in observational astronomy—is actually three rings. The rings are probably made up of bits of material ranging from the size of a grain of sand to the size of an automobile. Composed of such relatively minute particles and only about ten miles thick, the three bands are quite transparent.

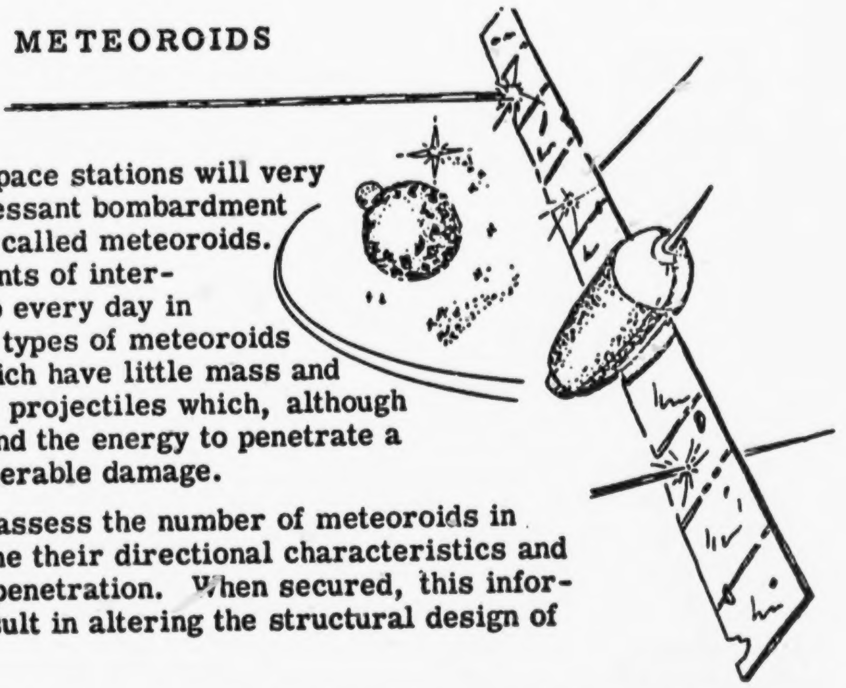
Science writers have long been intrigued by Saturn's bands, rings, and the moons but have had very little data to draw upon in trying to envision the planet's surface conditions. In picturing the scene which might greet a visitor, many of them begin by describing the frozen, crystalline atmosphere of the planet, whose name was borrowed by chemists many years ago to designate an odd crystalline structure as "the tree of Saturn."



To observe the development of crystals, suspend a strip of zinc polished with a piece of sandpaper in a solution of a teaspoon of lead acetate dissolved in a half pint of hot water. Let it stand overnight and observe the delicate crystalline growth coating the zinc. Note the change in growth for the next few days. (Through chemical action, the zinc drives the lead out of the lead acetate solution and zinc acetate is formed. Metallic lead appears as the crystals form on the zinc strip.)

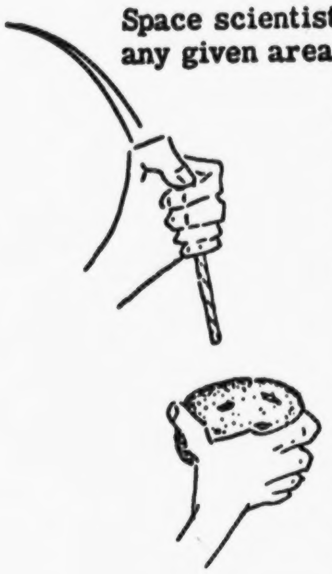
Reference: Asimov, Isaac. Building Blocks of the Universe. New York: Abelard-Schuman, 1961.

SPACE BULLETS - METEOROIDS



Astronauts who man orbiting space stations will very probably be exposed to the incessant bombardment of fast moving space particles called meteoroids. Many millions of these fragments of interplanetary debris are burned up every day in the earth's atmosphere. Two types of meteoroids are known: the dust balls, which have little mass and could do little damage; and the projectiles which, although relatively small, have mass and the energy to penetrate a spacecraft and to cause considerable damage.

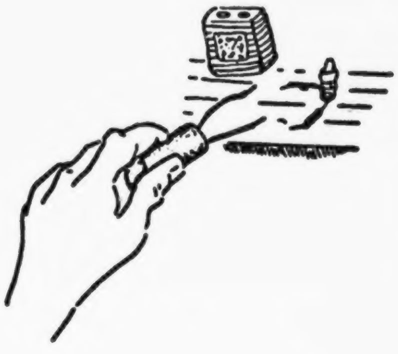
Space scientists are trying to assess the number of meteoroids in any given area and to determine their directional characteristics and their power of penetration. When secured, this information may result in altering the structural design of spacecraft.



To show the penetrating power of a small projectile which has mass and high velocity, hold a raw potato and a soda straw as shown. With a quick, sharp motion, stab the potato with the straw. Notice how easily the straw penetrates the potato. Try a slower thrust and observe the result.

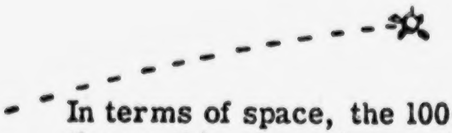
One method for determining the nature of meteoroids is to use test panels, made of various structural materials and enclosing a capacitance cell, which are flown through space. When the cell is penetrated by a meteoroid, the cell's electrical charge is neutralized. The manner in which this occurs indicates to space scientists, who are monitoring the test panel from earth, the specific characteristics of the meteoroid involved. (A cell which has been neutralized by a meteoroid is then recharged for further monitoring.) A 2000-microfarad, 15-volt, electrolytic capacitor from an electronic supply store is a good example of a capacitance cell. Its two plates, instead of lying flat as in the sensing cell of a spacecraft, are rolled up to save space in electronic equipment.

A capacitor is an apparatus which stores electricity. In very simple form, it is composed of two conducting sheets of aluminum foil separated by a good insulating substance such as oiled paper. Virtually no electrons can move through the paper to complete the circuit between the plates.



Place an electrical charge from a 9-volt D. C. battery (never use A. C.) into a capacitor, as described above, from an electronic supply store. Touch the terminals across the lead wires from a No. 222 pilot lamp and a 3.2 ohm resistor, as shown in the diagram at the left. Notice the discharge of electricity in the lamp.

THE ATMOSPHERE

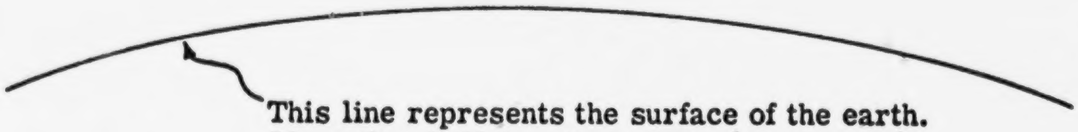


In terms of space, the 100-mile layer above the earth's surface constitutes the earth's atmosphere. Space scientists consider this to be the earth's atmosphere because spacecraft flying anywhere below this altitude will encounter frictional drag. That is, they will collide with air molecules, slow down, burn, and be destroyed.

The earth's atmosphere is a relatively small area. But even within this narrow band, the greatest density of the air (the greatest concentration of air molecules) is very, very close to the earth's surface. About one-half of all the air above us is packed into the first 18,000 feet. This is only about three and a half miles above sea level and two miles below the top of Mt. Everest. Most of the weather, a product of air movement, occurs within the five-mile area above sea level.

(Many aircraft can fly up to eight miles. For exploring the atmosphere between the highest aircraft or balloon flight and the lowest satellite orbit, a small, relatively inexpensive rocket is used to probe the skies.)

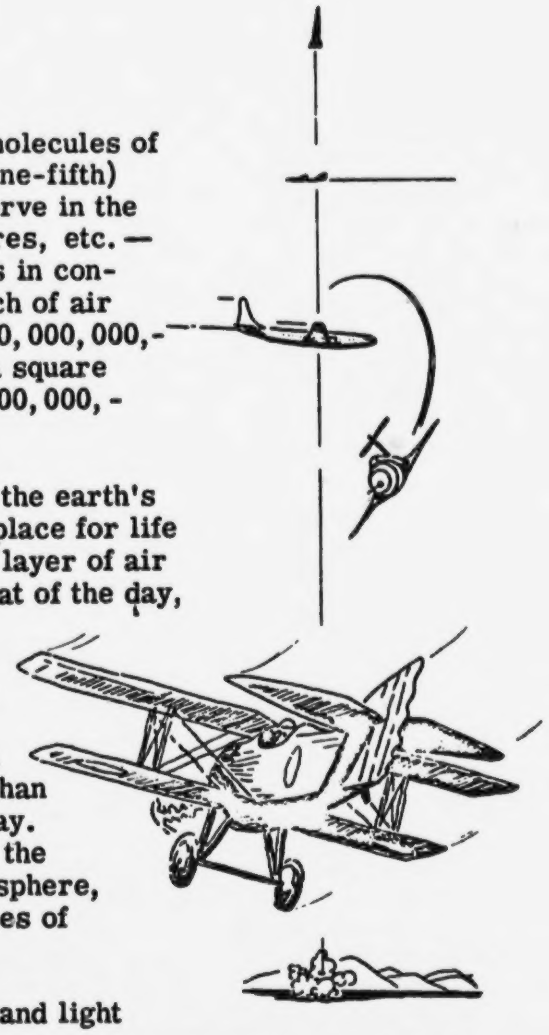
Reduced to an easily grasped scale, half the air over a globe one foot in diameter would be the thickness of a human hair. The height of Mt. Everest would equal the thickness of two hairs; the highest balloon flight, the thickness of a piece of grocery string. And a close orbiting satellite would be less than half an inch away!



This line represents the surface of the earth. More than half the atmosphere (air density) lies within the thickness of the line.

Reference: Loesack, Theo. Our Atmosphere. New York: Mentor, 1961.

AIR MOLECULES

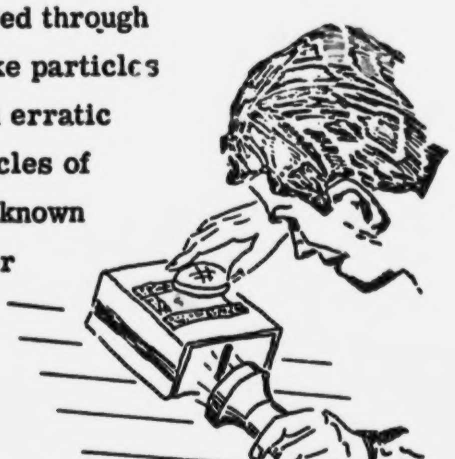


The air we live in—and breathe—is made up of molecules of nitrogen (approximately four-fifths) and oxygen (one-fifth) constantly in motion. Most of the effects we observe in the atmosphere—winds, clouds, atmospheric pressures, etc.—result from the collective motion of air molecules in continual collision with one another. In one cubic inch of air at sea level on an ordinary day, there are 443,300,000,000,000,000,000 molecules! In one second of time, a square inch of surface at sea level is bombarded by 80,000,000,000,000,000,000,000 molecules!

Without the infinity of molecules which composes the earth's atmosphere, the earth would be an uninhabitable place for life as we know it. Held to the earth by gravity, this layer of air absorbs deadly rays from the sun, retains the heat of the day, and stabilizes temperatures.

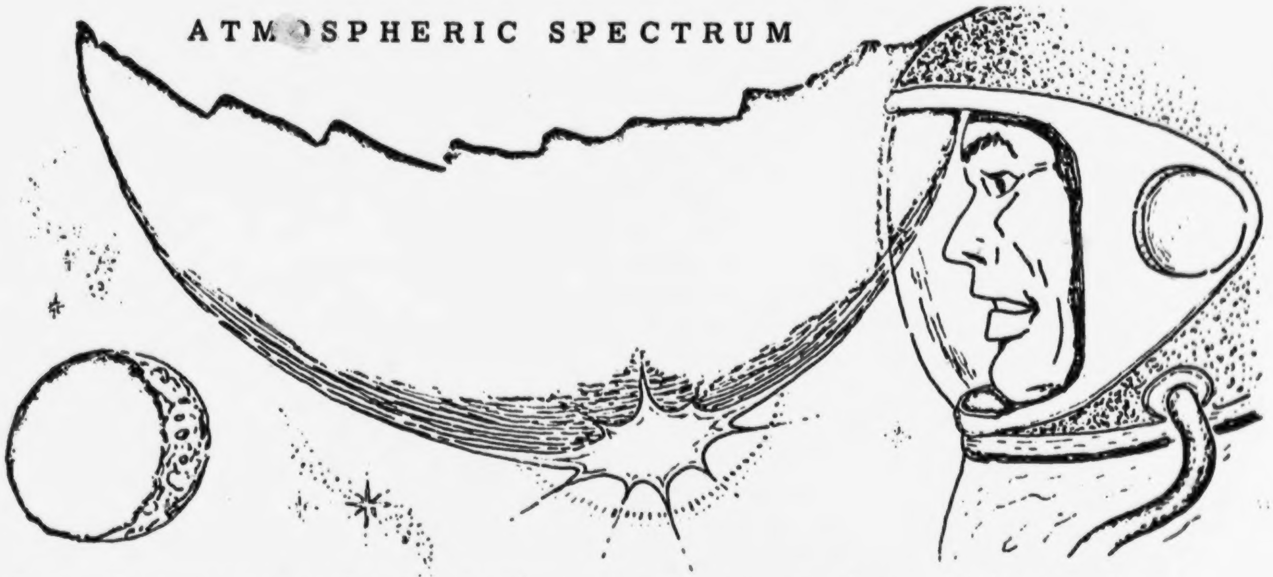
For flying, the atmosphere offers both problems and answers. It creates retarding forces which slow down aircraft, an effect which builds up to a barrier when the velocity of the craft is greater than the speed of the molecules in moving out of the way. Then the craft experiences what we call breaking the sound barrier. On the other hand, it is the atmosphere, acting on the ailerons, stabilizer, and tail surfaces of an airplane, which permits us to navigate it.

By looking at some solid substance small enough and light enough in weight to be moved when struck by molecules, it is possible to see that molecules are constantly bumping into each other. As shown in the illustration, paint the inside of a large matchbox black. Cut a slit in its drawer and a window in its top. Cover both openings with clear plastic. Have someone blow smoke into the box and close it quickly. Shine a shielded light through the slit so that the light's beam passes under the window in the top. When observed through a hand lens or a low-power microscope, the smoke particles in the beam of the light will be seen to move in an erratic manner. (Be sure to observe the individual particles of smoke.) This motion, first observed in 1827 and known as the Brownian movement, occurs when a greater number of air molecules in one side of the box than in the other strike the smoke particles.



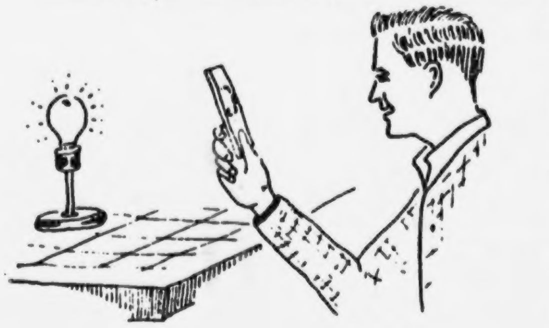
Reference: Orr, Clyde Jr. Between Earth and Space. New York: Macmillan, 1960.

ATMOSPHERIC SPECTRUM

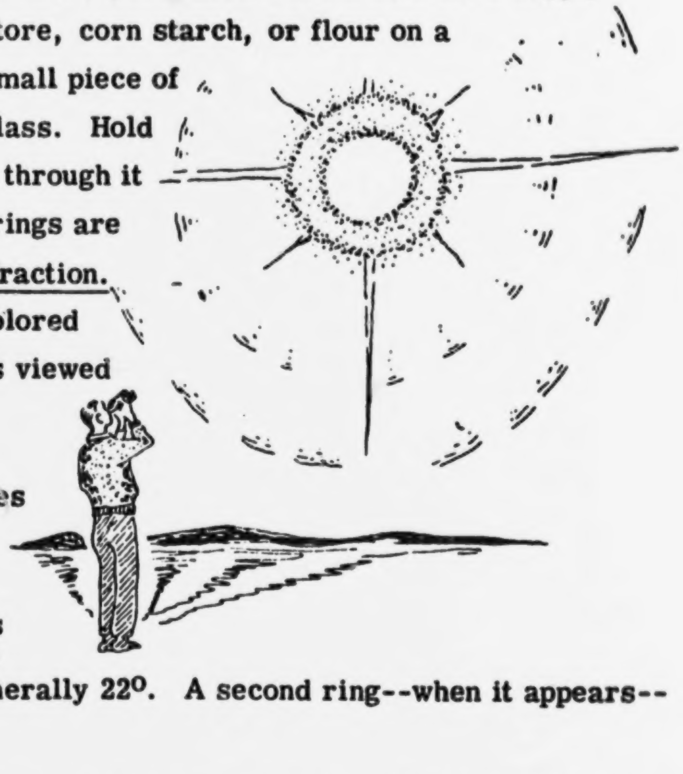


Space phenomena are often fascinating, sometimes mysterious. High above the atmosphere, astronauts may discover comets very close to the sun. They may observe the zodiacal light, a luminous band around the earth caused by the scattering of sunlight by interplanetary dust. At sunset and sunrise, they may witness the sun's corona and, by using a green filter, they may see the airglow of the atmosphere. They may be able to determine the limiting magnitude of certain stars or detect the two natural, cloudlike satellites which travel at the earth's libration points.

But some space phenomena, with proper analysis, can be related to observations already made from the earth's surface. Examples of the latter are the beautifully colored horizons at sunset and dawn, which astronauts always experience in orbital flights.



Such an effect can be experienced in minature by dusting a small quantity of lycopodium powder, purchased from a scientific supply store, corn starch, or flour on a small piece of glass. Hold the glass close to your eyes and look through it at a distant light bulb. The colored rings are produced by a phenomenon called diffraction. The same effect is produced in the colored borders which encircle bright objects viewed through fog.

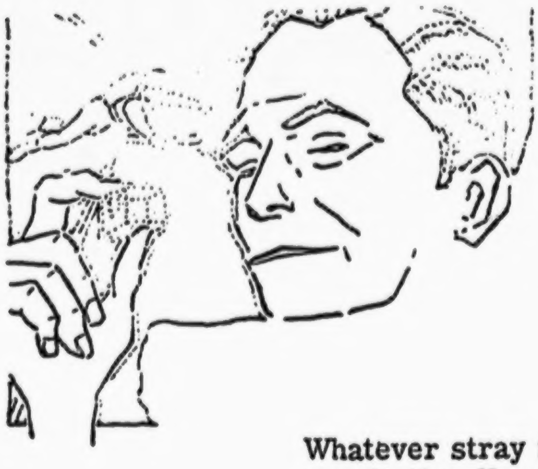


Coronas and glories of the sun and moon are caused by moisture particles in the air.

Halos, larger rings around the sun and moon, are caused by ice crystals floating high in the atmosphere. The radius of lunar and solar halos is generally 22°. A second ring--when it appears--is 46°.

Reference: Heuer, Kenneth. An Adventure in Astronomy. New York: Viking, 19 .

SPACE ENVIRONMENT

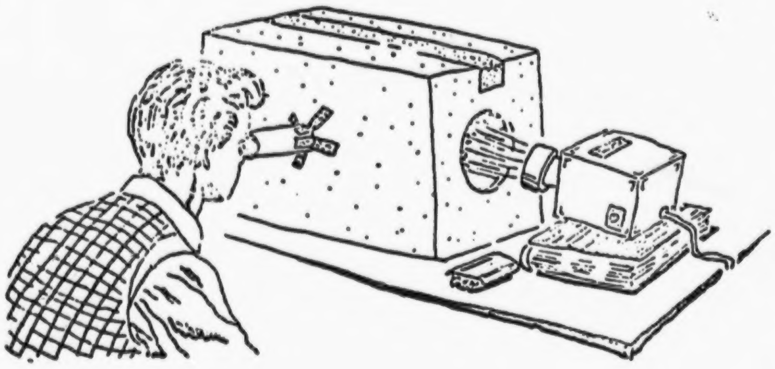


In deep space, there is essentially no atmosphere. There are so few molecules that pressure cannot be readily detected and neither heat nor sound energy can be conducted. Actually, space makes a good insulator against thermal and sound energy. (Since there is no conducting medium in space, the earth receives its thermal energy from the sun in the form of radiant energy.)

Whatever stray molecules there may be in space tend to be gravitationally attracted to the nearest body of matter, with the larger bodies and planets exerting greater attraction than the smaller. (The Moon, accordingly, with a mass of only 1.23% of the Earth's, exerts a relatively minute graviational attraction and has little atmosphere. Jupiter, on the other hand, with its tremendous mass of 318.35 times the Earth's, has an atmospheric pressure at its surface considerably greater than our own. The very force of the pressure, however, tends to act on the composition of Jupiter's atmosphere, hugging the heavier gases close to its surface and not allowing even the lighter gases of the next atmospheric layers to escape. This makes Jupiter's atmosphere vastly different from Earth's.)

Capsules and artificial satellites can fly through space without being slowed by molecular bombardment. However, they experience the disadvantage of not being able to use the atmosphere as an aid in manoeuvring and, in addition, of having to take along their own oxygen for burning the propellant, since there is none available in space.

Paint the inside of a large cardboard box with flat black paint (to stop reflection of light). Cut a smaller hole in one side and a larger hole in the other so that a beam of light from a projector will pass straight through without striking the box. Then, cut a hole in the box front large enough to insert a cardboard mailing tube. Paint black the inside of a six-inch section of mailing tube and tape it in place in the box front. Peering through the tube, compare the beam of light when no particles are in the air and after two chalkboard erasers have been clapped together in front of one of the holes.

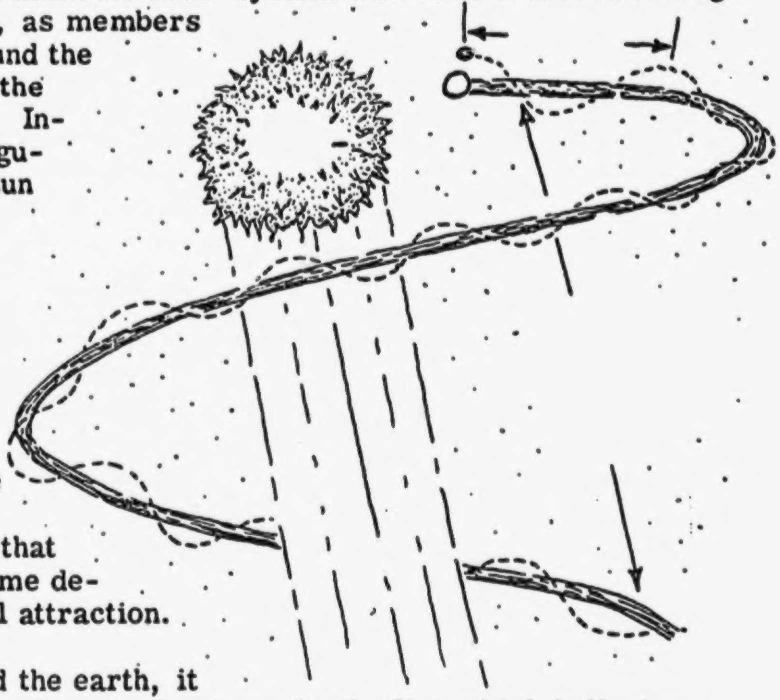


Hang a small ball inside the box, from the top, so that it can be seen through the viewing tube. Note the change in lighted area under different conditions of particle density.

Reference: Honegger, Gottfried and Peter Van de Kamp. Space - The Architecture of the Universe. New York: Dell Publishing Co. Inc., 1962.

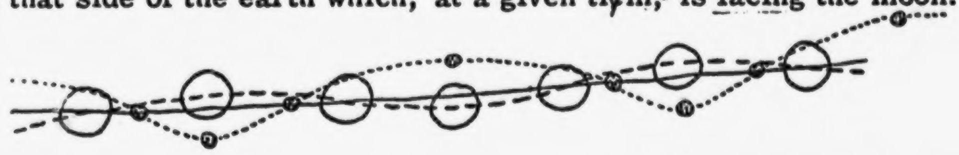
THE EARTH-MOON SYSTEM

Imagine a man whirling a lariat around his head as he walks down the street. In much the same manner, the sun takes its solar system with it as it moves through space. The earth and the moon, as members of the solar system, travel around the sun, but their paths do not take the form of a smooth, even ellipse. Instead, the earth follows an irregular, wobbly course around the sun and the moon, as shown in the illustration at the right, orbits around the earth in making the same journey. Together, they constitute constitute the earth-moon system.

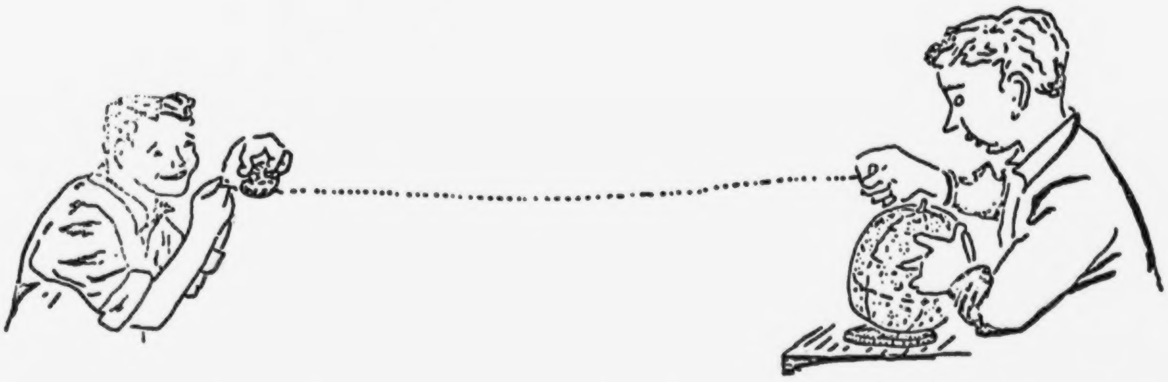


The reason behind the system relationship of the earth and the moon is that the earth, despite a mass which is about 80 times that of the moon, is influenced to some degree by the moon's gravitational attraction.

Although the moon orbits around the earth, it does not do so in a series of even loops. As shown by the line which indicates the system's path, in the illustration immediately below, the earth and the moon rotate around a moving point which is about a thousand miles below the earth's surface on that side of the earth which, at a given time, is facing the moon.



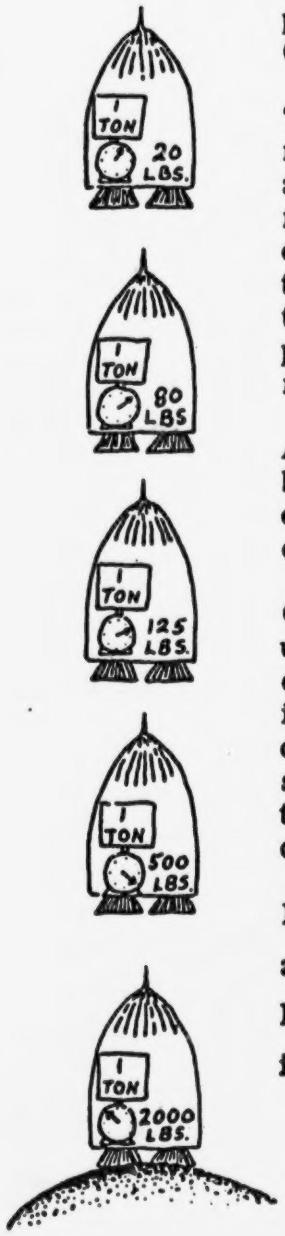
The distance between the moon and the earth is about 240,000 miles. An average globe representing the 7900-mile diameter of the earth is one foot in dimater. The moon's diameter is only about one-fourth that of the earth, or 2000 miles. Compared with the one-foot model of the earth, a model moon would be three inches in diameter, about the size of a tennis ball. Using the same scale, 30 feet would represent the distance between the earth (the globe) and the moon (the tennis ball).



Reference: Firsoff, V. A. Strange World of the Moon. New York: Basic Books, 1960.

THE EARTH'S GRAVITY

A series of basic statements can be made about the earth's gravity. Its pull holds you on the earth's surface and pulls back objects that you throw into the air. The pull, however, decreases as the distance between the earth and an object increases. Correspondingly, the weight of any object decreases as the distance between it and the earth increases, even though the object's bulk, or mass, remains the same. As an example, Echo I, the hundred-foot balloon which on August 12, 1960, became the first communication satellite, weighed 100 pounds on the earth's surface; placed in a 1000-mile orbit, it weighed only 64 pounds.



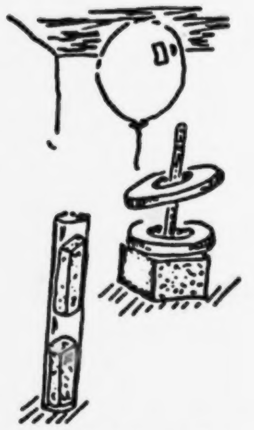
The weight of any object in space equals the mass of that object times the gravitational attraction at that particular location. Stated mathematically, if m represents the number of units of mass in a body and g represents the number of units of attracting force, then the body's weight, or w is equal to m multiplied by g. Or, $w = mg$ and, inversely, $m = w/g$.

An object which has gone into orbit around the earth, however, is in a weightless condition because the earth's gravitational pull is balanced by the object's circular motion.

Calculation of orbital paths and velocities by space scientists is based upon the fact that the weight of an object above the earth's surface decreases as the square of the distance from the center of the earth increases. The solution is in a simple, ratio problem form: The distance the object is from the earth's center, squared, is to the surface distance from the earth's center (4000 miles), squared, as the weight of the object on the earth's surface is to the weight of the object at its distance away from the earth.

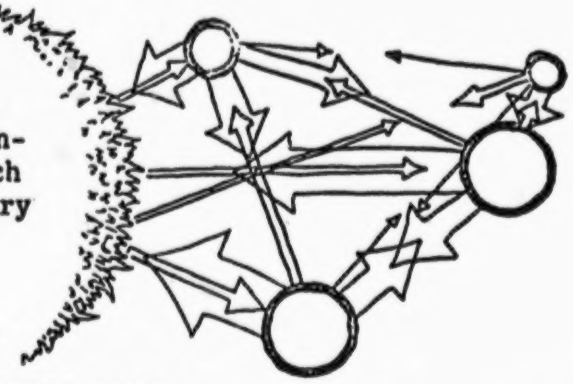
Follow the above ratio to its conclusion, using figures from the example already cited of Echo 1, like this: (5000 mi.) : (4000 mi.) :: 100 lbs. : x Its weight decreases in the ratio of $\frac{4000}{5000} = \frac{16}{25}$. Therefore, it would weigh 16/25 X 100 lbs., or 64 lbs.

"Hanging" a toy balloon, charged with static electricity, on the ceiling and "floating" one bar magnet above another, as illustrated at the right, are also examples of balancing the downward pull of gravity.



Reference: Fenyo, Eva.. A Guided Tour through Space and Time. Englewood Cliffs, N. J. : Prentice-Hall, 1959.

UNIVERSAL WEIGHT

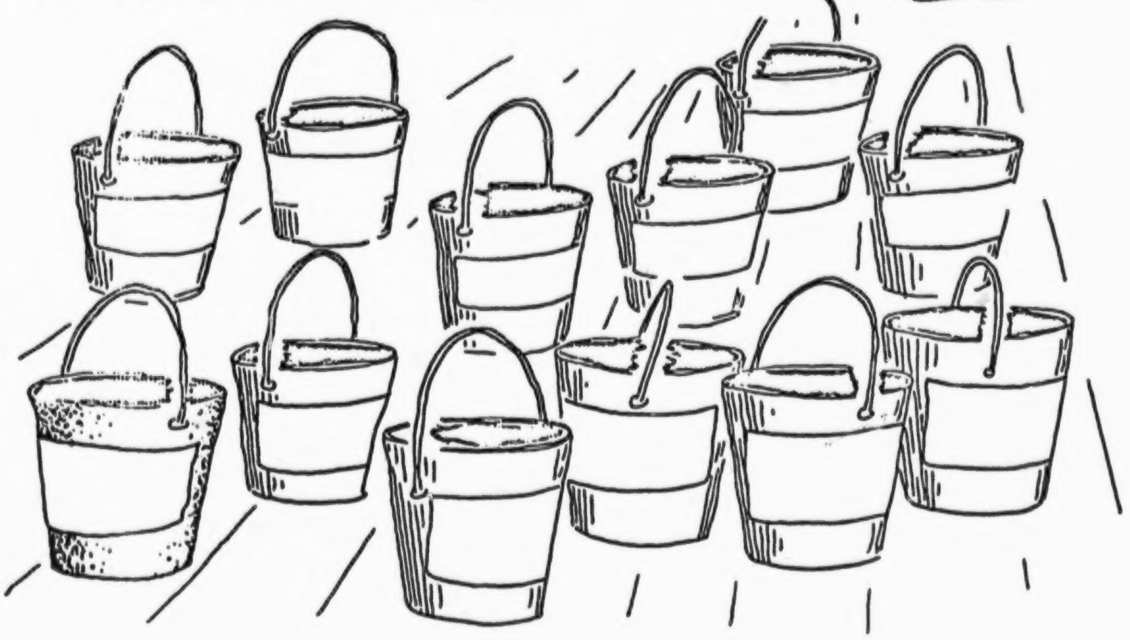


About three hundred years ago, the British scientist, Sir Isaac Newton, supplied a scientific reason why everything has weight. Each object in the universe, he said, pulls on every other object. This finding is called the Universal Law of Gravitation.*

Our sun has a pull strong enough to hold the earth and the other planets of the solar system in their orbits. Our planet, Earth, holds rocks, people, oceans, and the atmosphere on or near its surface and the moon in its orbit.

The weight of anything on Earth is a measurement of the amount of attraction between that object and the Earth. Located on another planet or star, the same object would have a different weight because other members of the solar system have different gravitational pulls.

The illustration below shows what an object weighing 10 lbs. on Earth would weigh on the various members of our solar system and on a large star.

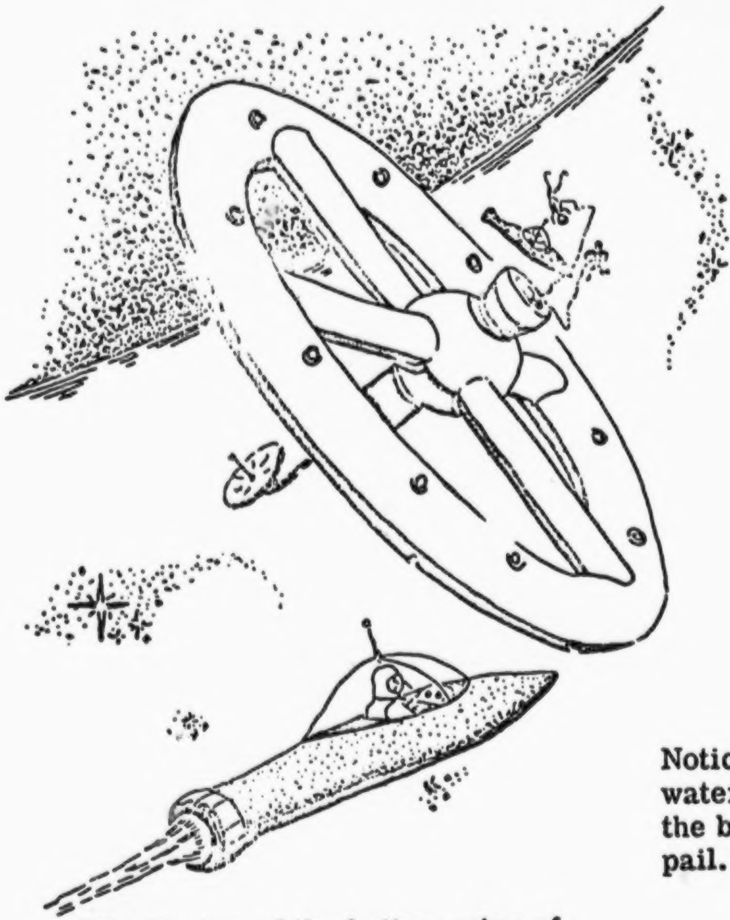


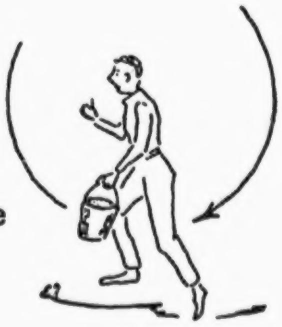
*** Every particle of matter in the universe attracts every other particle with a force proportional to the product of their masses and increasing as the square of the distance decreases.**

Reference: Hoyle, Fred. Frontiers of Astronomy. New York: Mentor, 1960.

ARTIFICIAL GRAVITY

Weightlessness can be eliminated in space stations and spacecraft by creating an artificial gravity. To accomplish this aim, wheel-like space platforms, whose slight, rotating motion will produce a sensation of gravity, are being developed. Men inside the space platforms will experience a feeling of weight and come to rest on the floor around the outside.

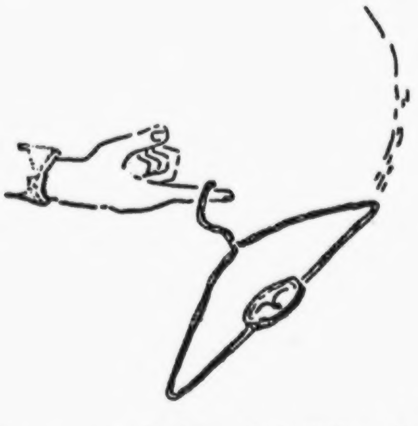


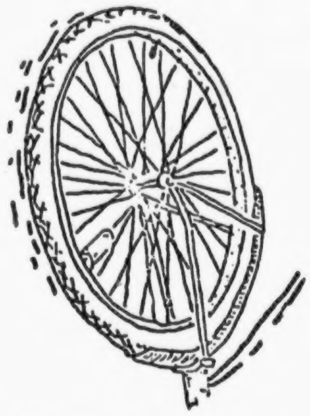


Notice how the water stays at the bottom of the pail.

File the top of the bottom wire of a metal coathanger flat. Place a heavy coin at the center; hand the coathanger by its hook on your fingertip and swing it around. Notice how the coin stays in place as the coathanger goes 'round and 'round.

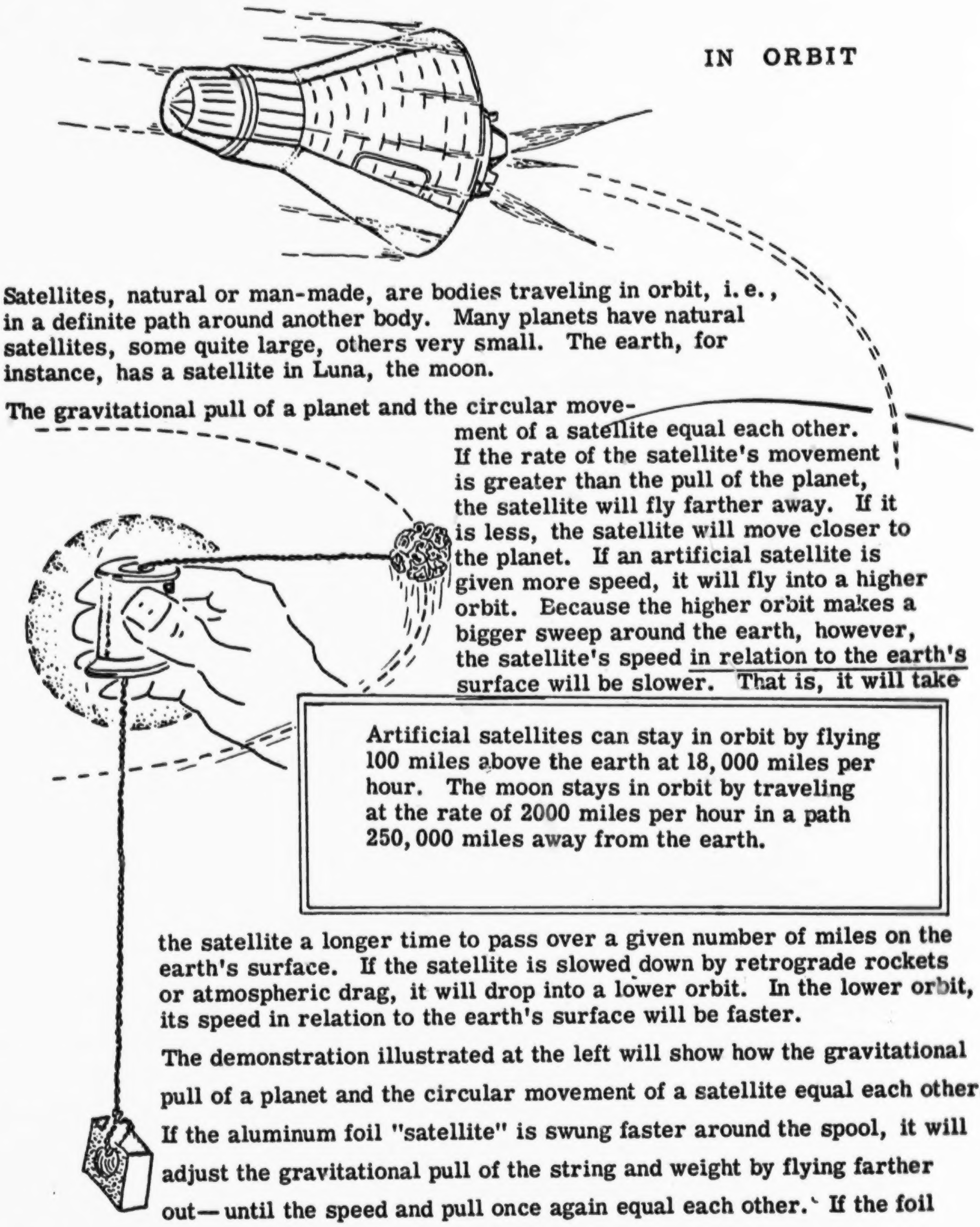
Slit a mailing tube down one side and place it around the spoke of a bicycle wheel. Rotate the wheel and notice that the force resulting from the spinning of the wheel is greater than the pull of natural gravity, so that the tube stays out next to the rim of the wheel.





Reference: Burgess, Eric. Satellites & Spacecraft. New York: Macmillan, 1957.

IN ORBIT



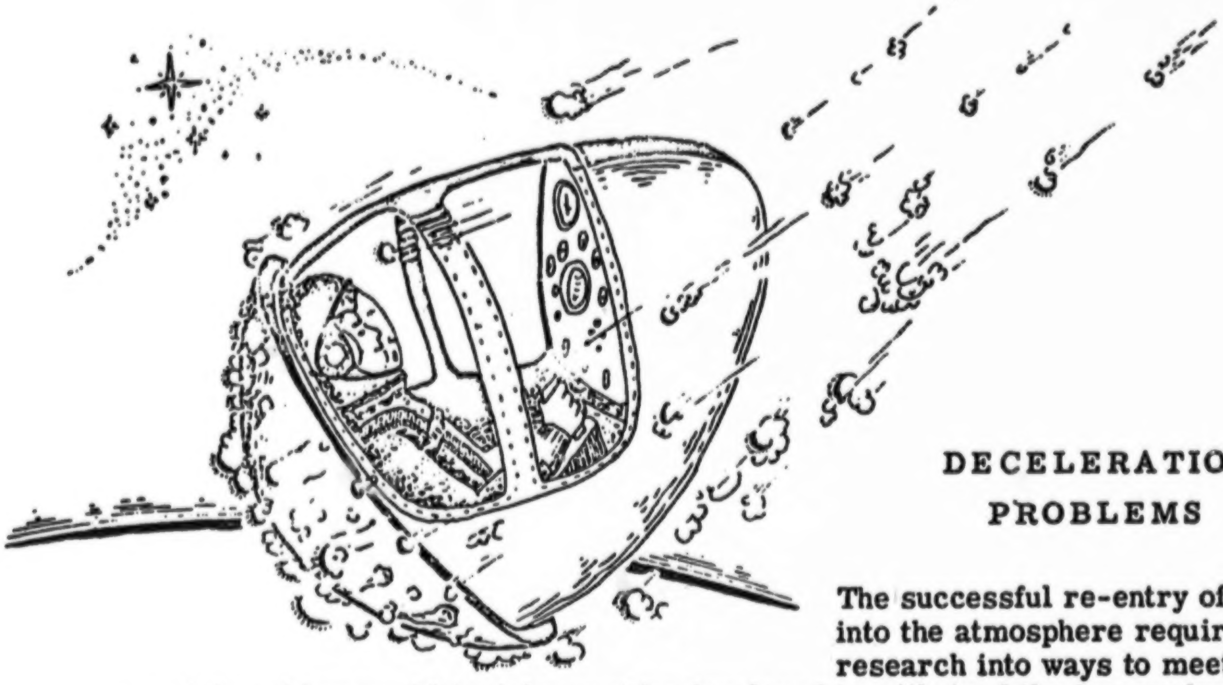
Satellites, natural or man-made, are bodies traveling in orbit, i.e., in a definite path around another body. Many planets have natural satellites, some quite large, others very small. The earth, for instance, has a satellite in Luna, the moon.

The gravitational pull of a planet and the circular movement of a satellite equal each other. If the rate of the satellite's movement is greater than the pull of the planet, the satellite will fly farther away. If it is less, the satellite will move closer to the planet. If an artificial satellite is given more speed, it will fly into a higher orbit. Because the higher orbit makes a bigger sweep around the earth, however, the satellite's speed in relation to the earth's surface will be slower. That is, it will take the satellite a longer time to pass over a given number of miles on the earth's surface. If the satellite is slowed down by retrograde rockets or atmospheric drag, it will drop into a lower orbit. In the lower orbit, its speed in relation to the earth's surface will be faster.

> Artificial satellites can stay in orbit by flying 100 miles above the earth at 18,000 miles per hour. The moon stays in orbit by traveling at the rate of 2000 miles per hour in a path 250,000 miles away from the earth.

The demonstration illustrated at the left will show how the gravitational pull of a planet and the circular movement of a satellite equal each other. If the aluminum foil "satellite" is swung faster around the spool, it will adjust the gravitational pull of the string and weight by flying farther out—until the speed and pull once again equal each other. If the foil ball is swung in a slower movement, it will fly closer to the spool.

Reference: Goodwin, Harold L. Space: Frontier Unlimited. New York: Van Nostrand, 1962.

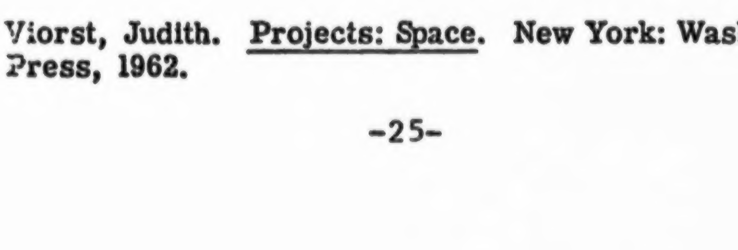


DECELERATION PROBLEMS

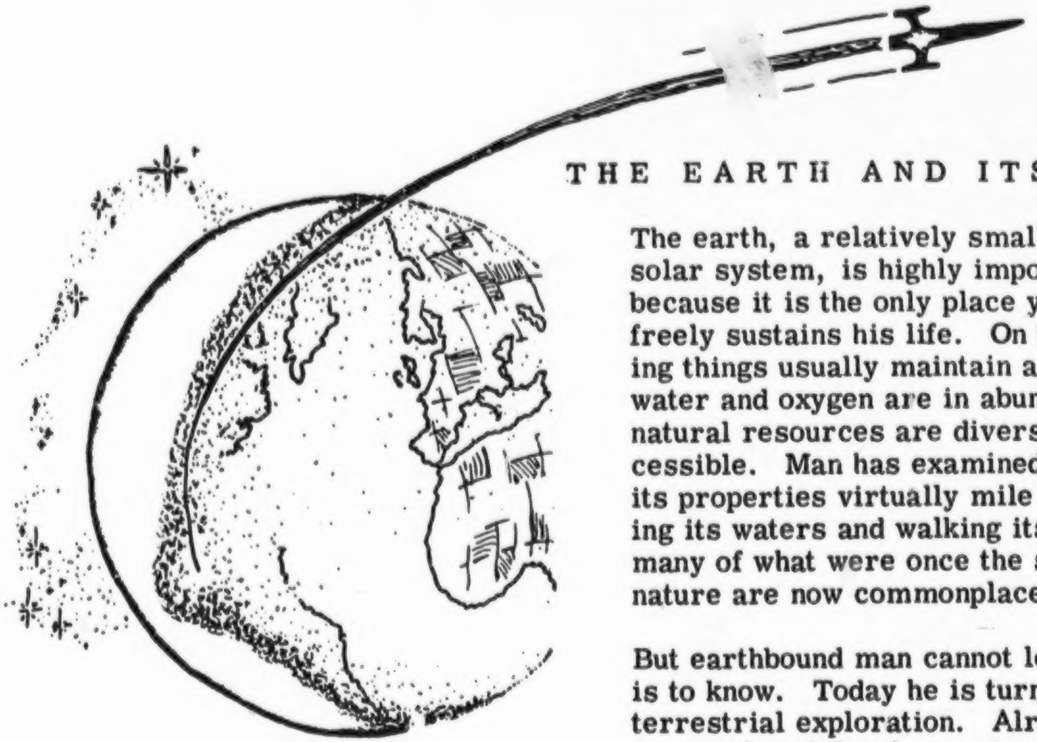
The successful re-entry of spacecraft into the atmosphere requires continuous research into ways to meet a series of crucial problems. Materials must be developed to withstand the tremendous frictional heat; instruments must be designed to stabilize flight; systems must be devised to maintain communication while an ionized layer of air blacks out radio waves. These are only a few of the important tasks involved.

Among the most serious problems are those related to the safety of the astronaut. On entering the denser atmosphere at 18,000 miles per hour, he encounters forces which for a few minutes multiply his weight by about eight. Couches have been specially designed for the manned capsules to help the astronaut withstand the tremendous pressures of deceleration.

To gain some understanding of what happens to an astronaut when he encounters deceleration, seat a doll at the back end of a shoe box which has been tied to a roller skate. Then give the skate a push so that it will roll across the floor and hit a brick. Repeat the experiment with the doll sitting with its back against the front end of the box. Note the difference in what happens to the doll in the second collision compared with the first.



Reference: Viorst, Judith. Projects: Space. New York: Washington Square Press, 1962.



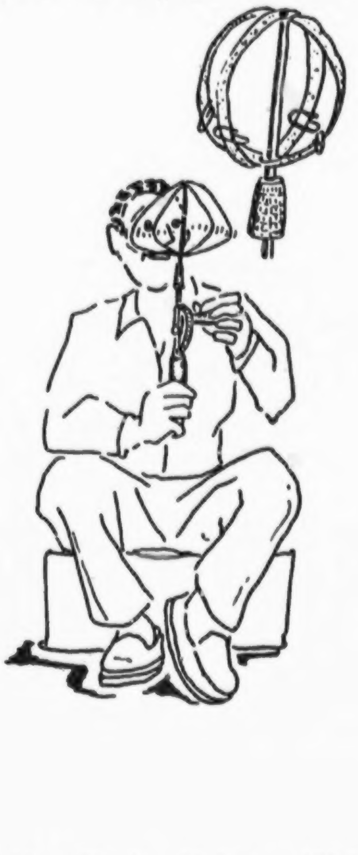
THE EARTH AND ITS SHAPE

The earth, a relatively small planet in the solar system, is highly important to man because it is the only place yet known which freely sustains his life. On the earth, living things usually maintain a natural balance, water and oxygen are in abundance, and natural resources are diversified and accessible. Man has examined the earth and its properties virtually mile by mile, sailing its waters and walking its land. Thus, many of what were once the secrets of nature are now commonplace facts.

But earthbound man cannot learn all there is to know. Today he is turning to extraterrestrial exploration. Already, scientific research and development programs have made great advances. Space scientists can see many things about the earth that could never be studied from its surface.

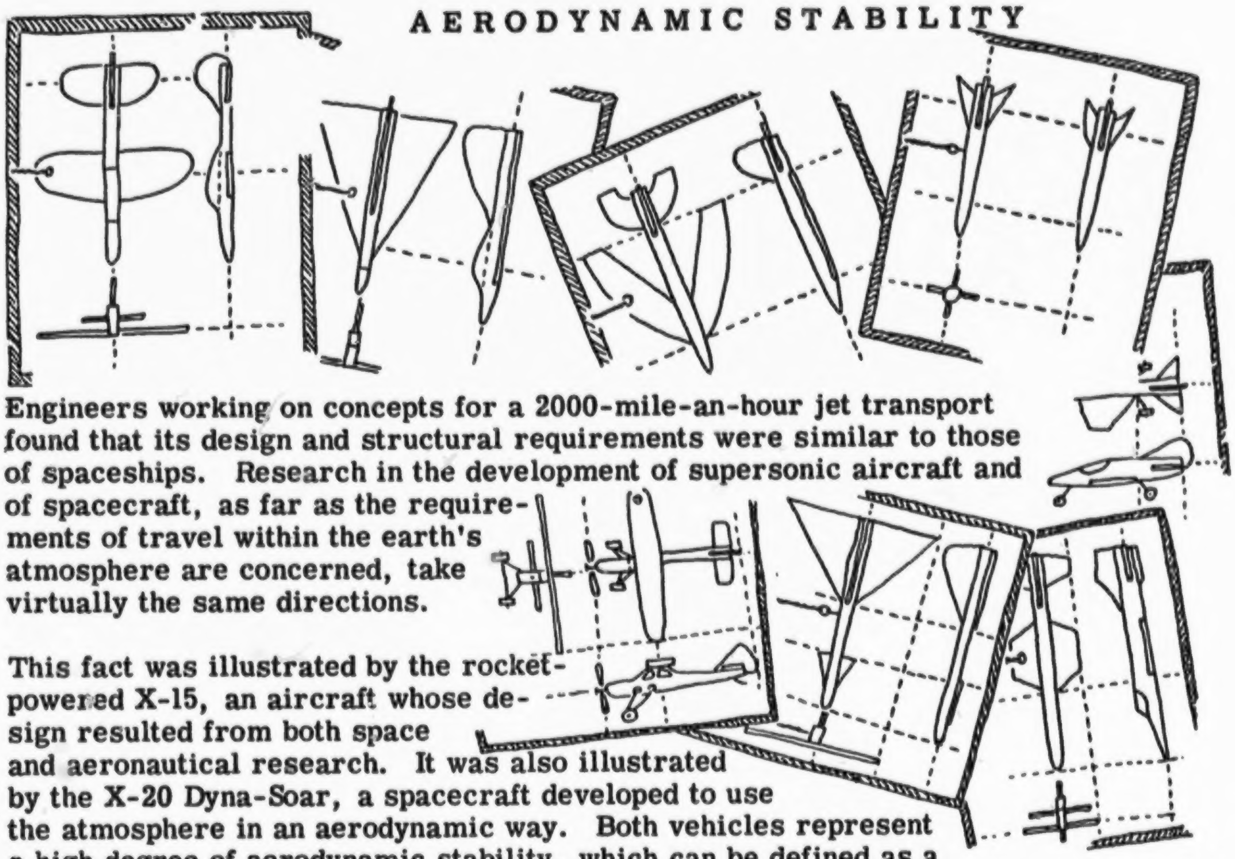
An example of this kind of space study is observation of the earth's shape. Although the earth is round, it is not a true sphere. It has flattened poles and a bulging equator. Its shape is known as an unsymmetrical oblate ellipsoid of revolution. The term comes from the fact that, as the earth revolves, its own irregular masses pull it from a round shape to a slightly pear shape.

Cut two lengths of light cardboard, about one inch wide, and arrange them in the shape of a sphere, using sticky tape. Attach the upper part of the sphere with a thumb tack to an axis made of a pencil; punch a hole in the lower part of the sphere so that it can slide up and down on its pencil-axis. Clamp the end of the pencil in a drill and slowly spin the drill. Attach paper clips (which simulate "irregular masses" on our sphere) at various points to the hoops and notice the modification in the sphere's shape when it is then spun.



Reference: Marshack, Alexander. The World in Shape. New York: Nelson, 1958.

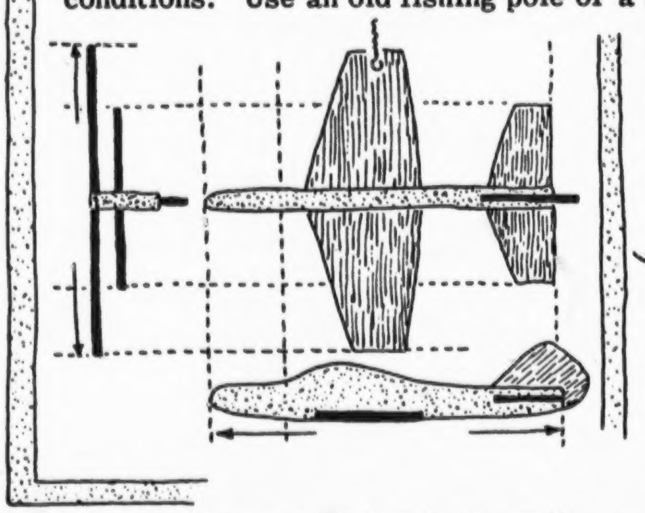
AERODYNAMIC STABILITY

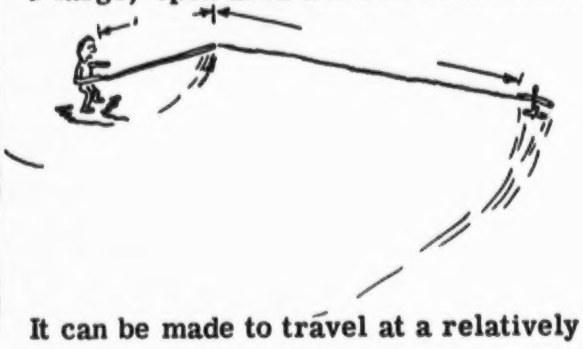


Engineers working on concepts for a 2000-mile-an-hour jet transport found that its design and structural requirements were similar to those of spaceships. Research in the development of supersonic aircraft and of spacecraft, as far as the requirements of travel within the earth's atmosphere are concerned, take virtually the same directions.

This fact was illustrated by the rocket-powered X-15, an aircraft whose design resulted from both space and aeronautical research. It was also illustrated by the X-20 Dyna-Soar, a spacecraft developed to use the atmosphere in an aerodynamic way. Both vehicles represent a high degree of aerodynamic stability, which can be defined as a normal condition of flight for aircraft or spacecraft within the earth's atmosphere.

Models can be tested for aerodynamic stability in design under simulated flight conditions. Use an old fishing pole or a long stick and a piece of string as the power source. Stand in the center of a large, open area and twirl the model.



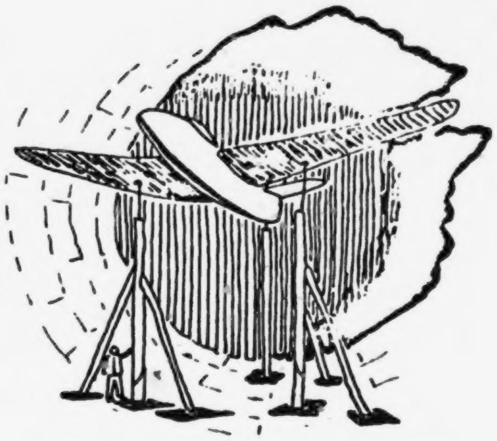


It can be made to travel at a relatively high speed.

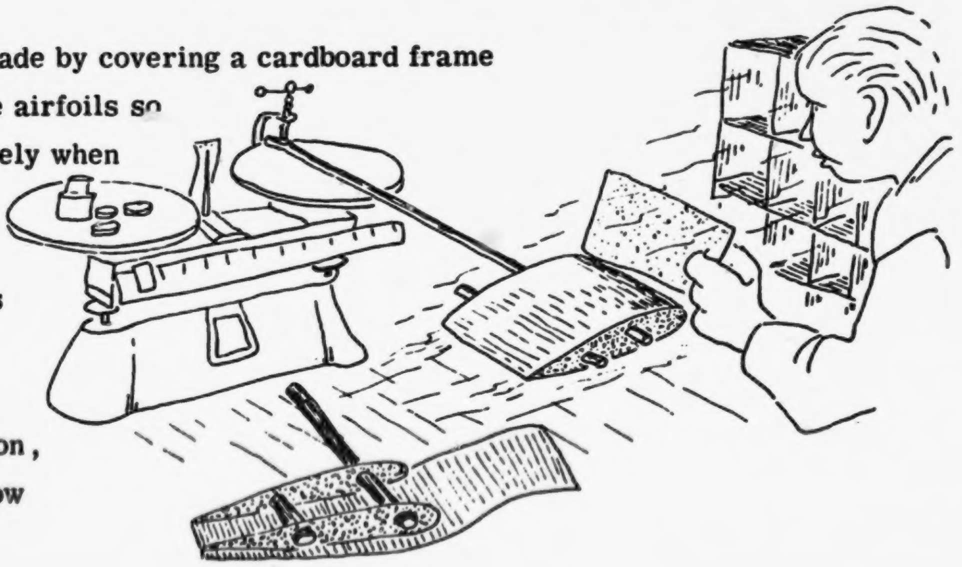
The speed of the model in relative miles per hour can be easily calculated. With a model constructed to a scale of one foot equals 100 feet and testing it in a circle radius of 20 feet, divide 4000 by the time in seconds of one revolution.

Reference: Haggerty, James J., Jr. 1963 United States Aircraft, Missiles, and Spacecraft. Washington, D. C.: National Aerospace Education Council, 1963.

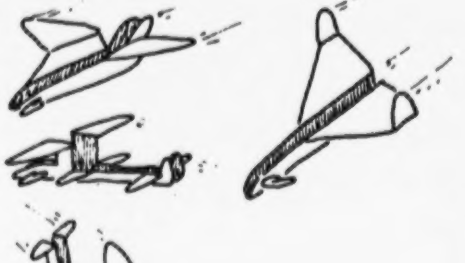
AERODYNAMIC RESEARCH



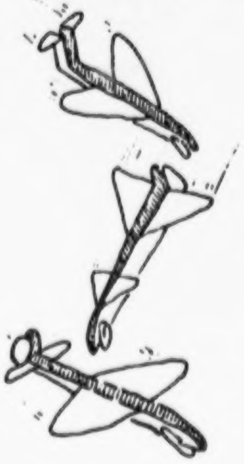
Ever since the time of the Wright brothers, wind tunnels have been used to simulate flight conditions in solving the most critical problems of aircraft development. In the artificial situations provided by these flight simulators, scale models of aircraft or even full-sized structures undergo rigorous testing at various speeds and under various stresses.

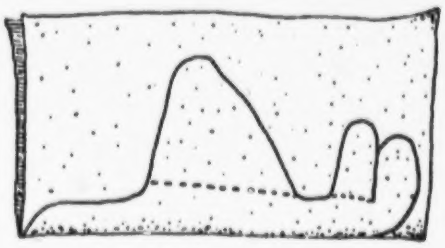


Test airfoils can be made by covering a cardboard frame with paper. Mount the airfoils so that they can move freely when a flow of air is directed toward them. Notice how the airfoils are affected when a cardboard strip, as shown in the illustration, is used to block the flow of air.



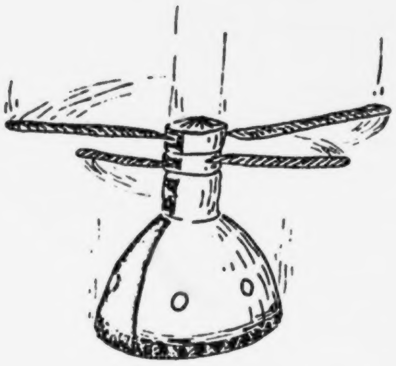
Simple, experimental shapes can be flight-tested by models cut in the desired shape out of a folded piece of stiff typewriter paper. Be sure that all parts you want are included. Weight with a paperclip or clay.

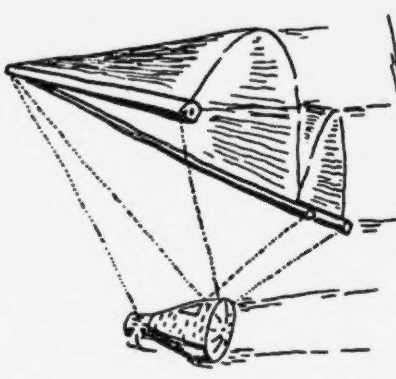


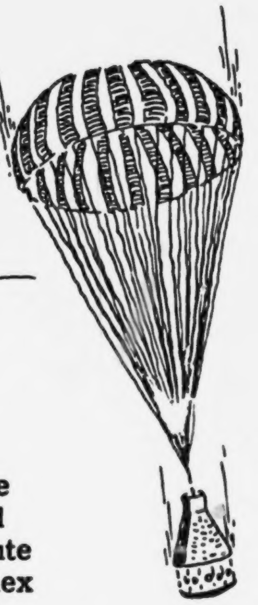


Reference: Shapiro, Ascher H. Shape and Flow. Garden City, N. Y.: Anchor, 1961.

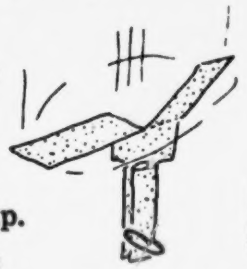
SOFT LANDING

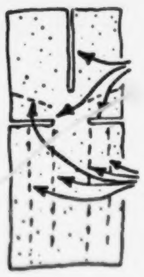




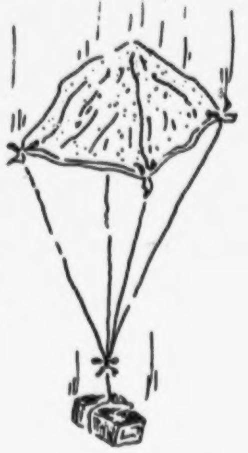


Designers of spacecraft work continuously on devices which can be carried folded or collapsed by ballistic re-entry vehicles and used when needed to provide a soft landing ability. The simple parachute has been most favored, but the folding helicopter blade and the "flex wing" (Ragallo) have characteristics which hold great promise for the future.

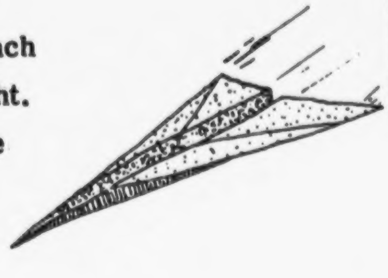


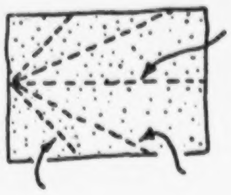


For an idea of the way these devices work, take a file card or piece of paper and cut it as shown in the illustration at the right. Fold the bottom section and fasten it with a paper clip. Adjust the vanes until the paper spins as it falls through the air. Note the rate of its fall as compared to that of a ball of paper.



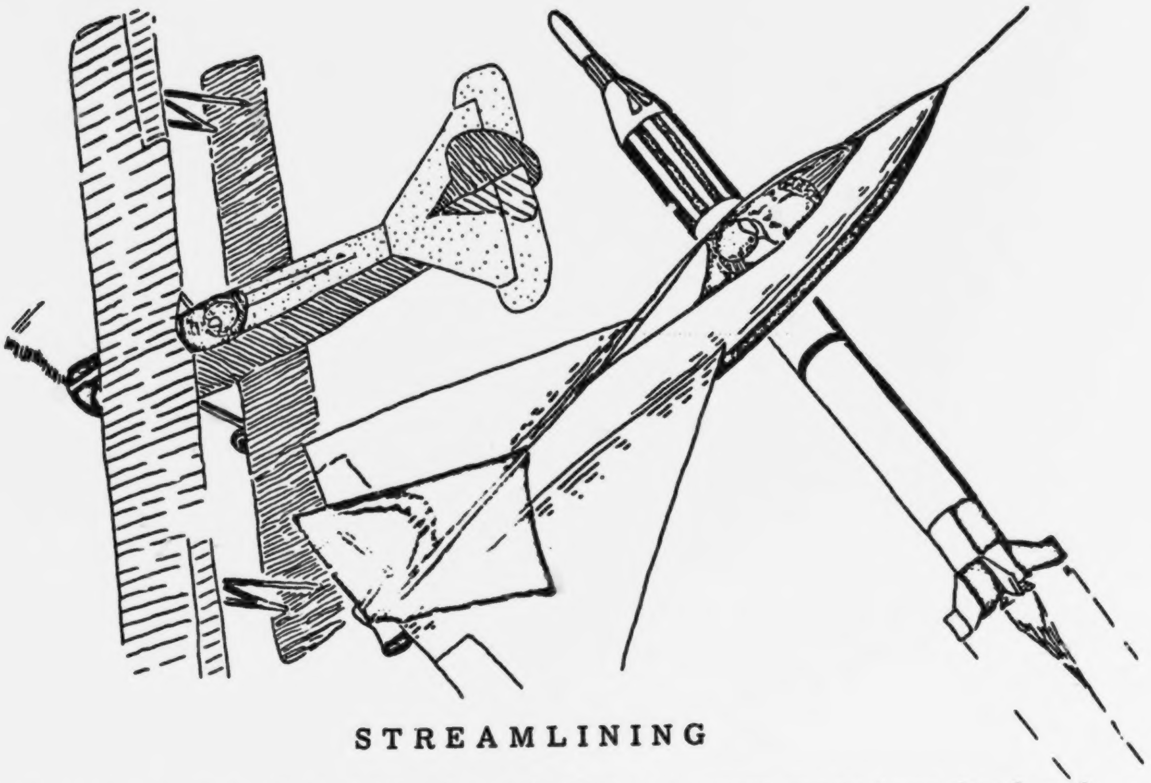
Tie strings about twelve inches long to each corner of a large handkerchief and fasten them together at their other ends, attaching a thumbtack box or other weight at the point of fastening. Roll the handkerchief and strings around the weight and throw it into the air. Compare the rate of fall with the parachute and then without the parachute.





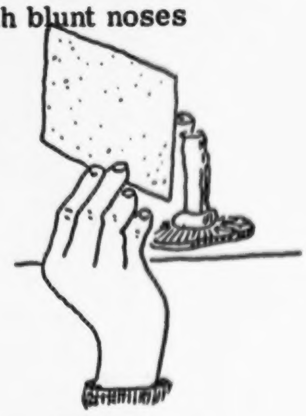
Fold a piece of standard 8 1/2 X 11-inch typewriter paper as shown at the right. Notice how it can be adjusted to glide slowly to the ground.

Reference: Tuchmann, Frederick K. Airplane Design Manual. New York: Pitman, 1958.



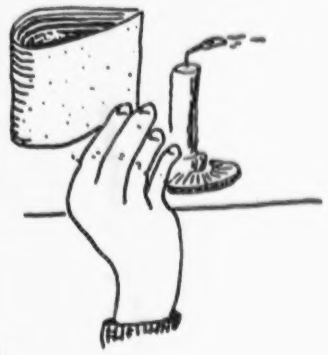
STREAMLINING

Using various types of wind tunnels, scientists in recent years have developed shapes for aircraft which allow each kind to perform more efficiently. As a result of this scientific work, high-speed airplanes are designed to look like sleek needles, with razor-sharp wings. Many spacecraft are designed with blunt noses so that they can use the earth's atmosphere to cushion re-entry.



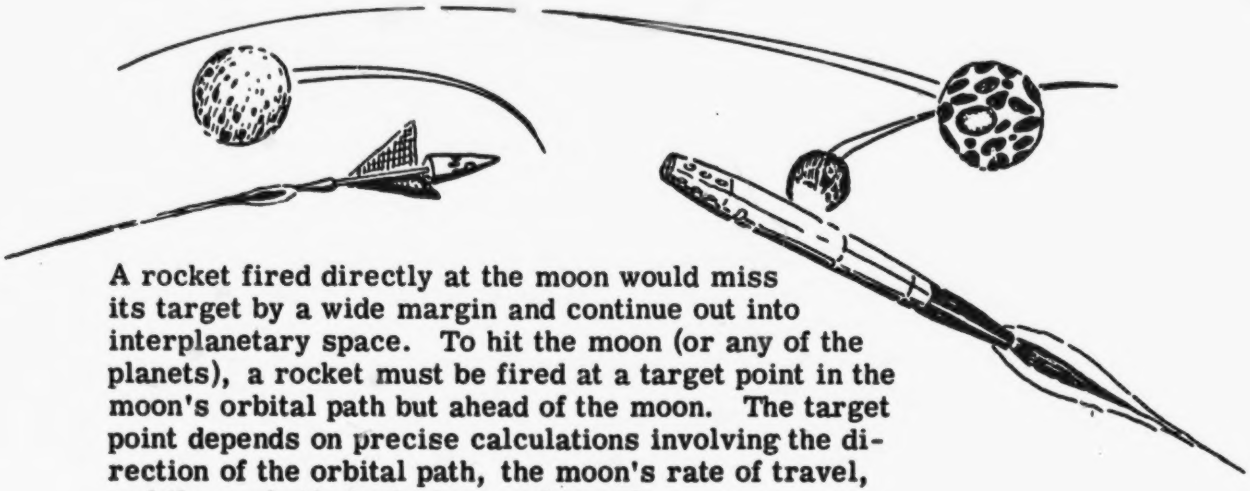
Streamlined designs have been developed for fast-moving vehicles of all kinds because they offer the least possible resistance to air. To show the way air affects the movement of different shapes, blow against a flat card held in front of a candle. Note how the flame is drawn toward the card. This indicates "drag" or a low-pressure air pocket behind the card.

In contrast to the first experience, bend a piece of cardboard in a tear-drop shape and note that as you blow the candle flame is pushed away by the air stream. The streamlined shape reduces pressure in front (try to feel this) and suctional drag in back.

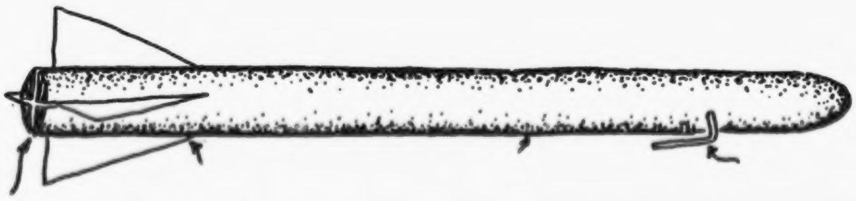


Reference: Shapiro, Ascher H. Shape and Flow. Garden City, N. Y.: Anchor, 1961.

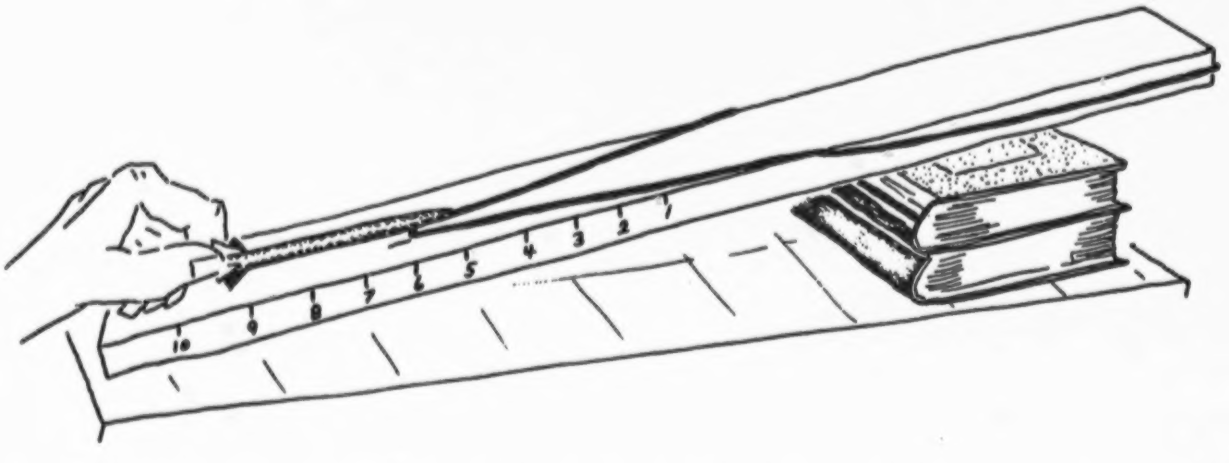
ROCKET PATHS



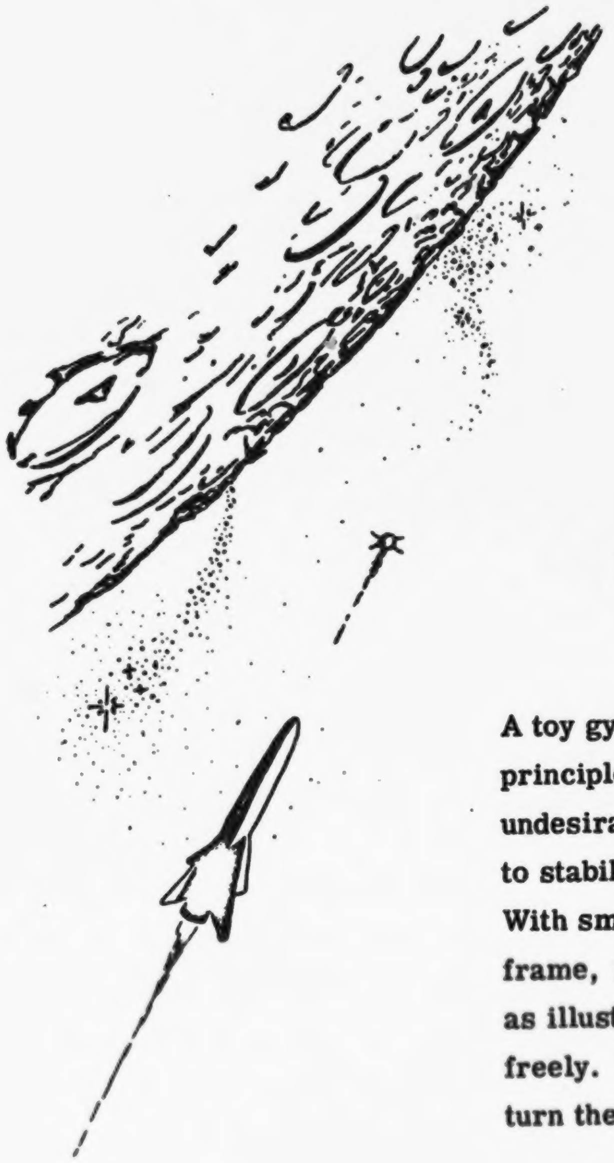
A rocket fired directly at the moon would miss its target by a wide margin and continue out into interplanetary space. To hit the moon (or any of the planets), a rocket must be fired at a target point in the moon's orbital path but ahead of the moon. The target point depends on precise calculations involving the direction of the orbital path, the moon's rate of travel, and the rocket's trajectory and speed.



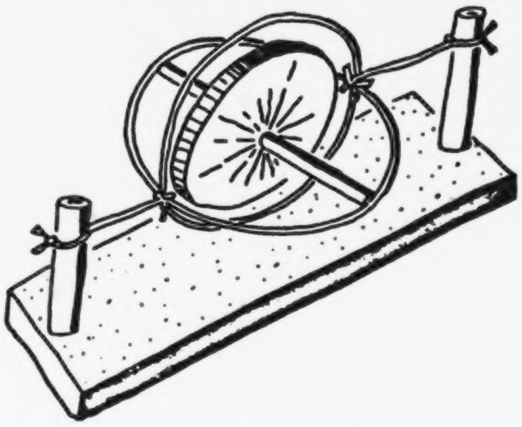
The arching shape of a rocket's trajectory can be observed in the action of model rockets and the use of a catapult made of a rubber band. (Although rockets are fueled, the fuel is expended so quickly that during a major portion of its flight a rocket functions like a free-falling object.) The initial energy of the model rocket can be varied by varying the amount of pull on the catapult. The height of the rocket's ascent will vary accordingly. The rocket's horizontal range can be varied by changing the launch angle. Note the typical parabolic shape of the trajectories.



Reference: Ovenden, Michael W. Artificial Satellites. Baltimore: Penguin, 1960.

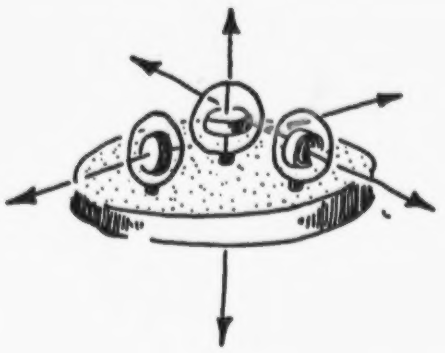


INERTIAL GUIDANCE



A toy gyroscope can be used to illustrate the principle behind the instrument which detects undesirable motions in launch vehicles and helps to stabilize many spacecraft while in orbit. With small elastic bands tied to its side cross-frame, mount a gyroscope in a wooden stand, as illustrated above, so that it will swing freely. When the wheel is spinning rapidly, turn the wooden base and note how the gyro tilts.

In a vehicle, an indicator attached to the gyro mounting senses changes in attitude and velocity and indicates the required corrective measures. A three-gyro inertial system, used in many of the more advanced vehicles, is mounted so that the sensitive axis of each gyro is perpendicular to each of the others. Through this system, it is possible to detect all of the vehicle's movements, such as yaw, pitch, and role.

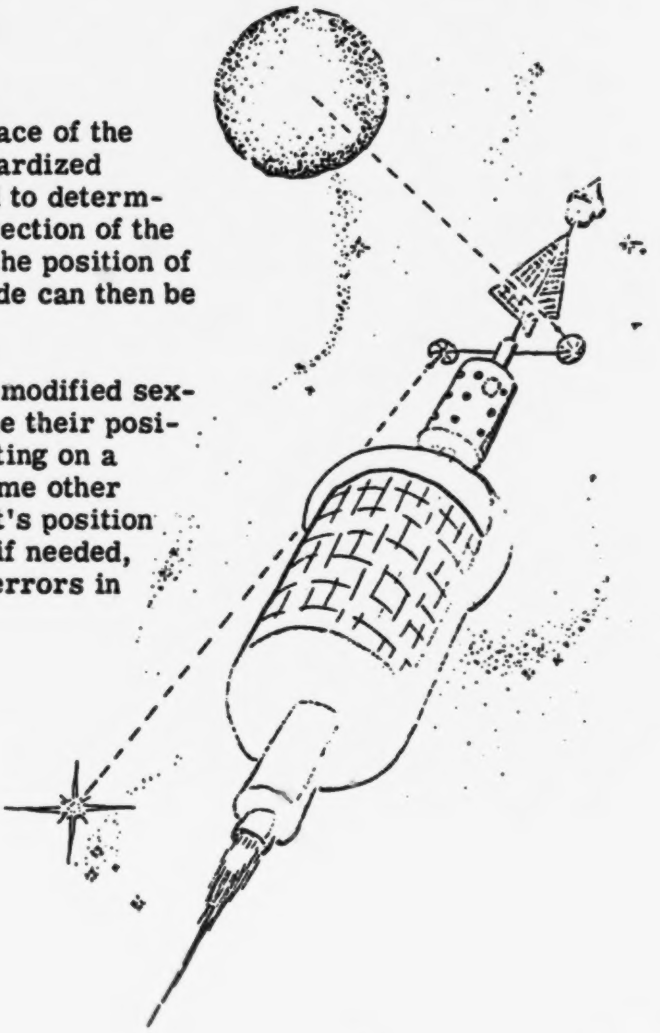


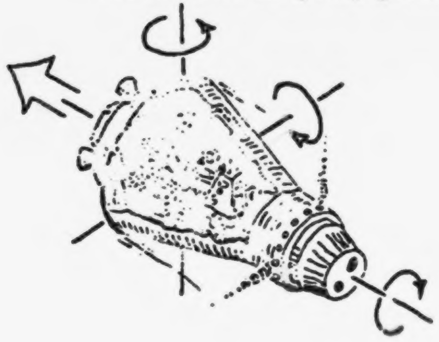
Reference: Sperry Gyroscope Co. The Gyroscope through the Ages. Great Neck, N.Y.: Sperry Gyroscope Co., Div. of Sperry Rand Corp., 1960.

SPACE GUIDANCE

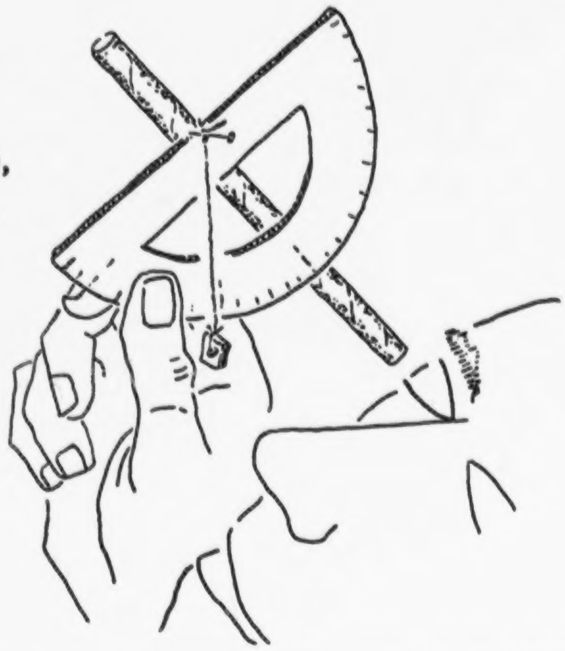
A sextant is used on or near the surface of the earth to determine latitude. A standardized chronometer (accurate clock) is used to determine longitude. By locating the intersection of the latitude and the longitude on a map, the position of the spot where the readings were made can then be determined.

Spacecraft and launch vehicles use a modified sextant-chronometer system to determine their position in space automatically. By sighting on a known object--a star, the sun, or some other satellite--at a certain time, the craft's position and direction can be calculated and, if needed, corrections made to overcome such errors in movement as yaw, pitch, and roll.



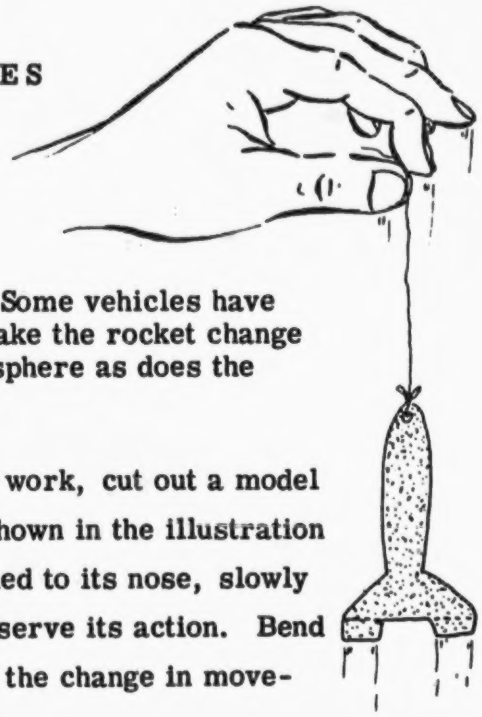


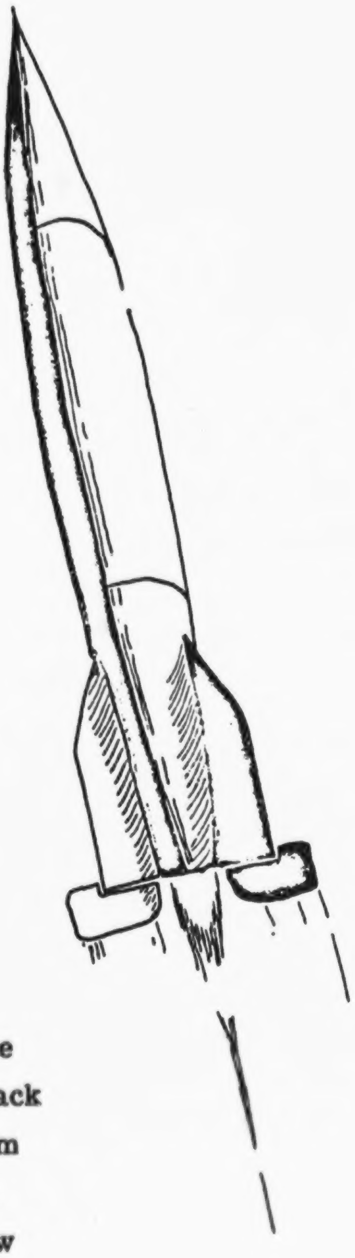
A simple sextant (clinometer) made as shown in the illustration at right from a protractor, soda straw, masking tape, pin, piece of thread, and a weight (nut, bolt, stone, or clay) will indicate how these readings are made. When finished, check the altitude of the North Star (Polaris). Compare the angle reading with your latitude as shown on a map.



Reference: Johnson, Gaylord and Irving Adler. Discover the Stars. New York: Sentinel, 1954.

GUIDANCE VANES

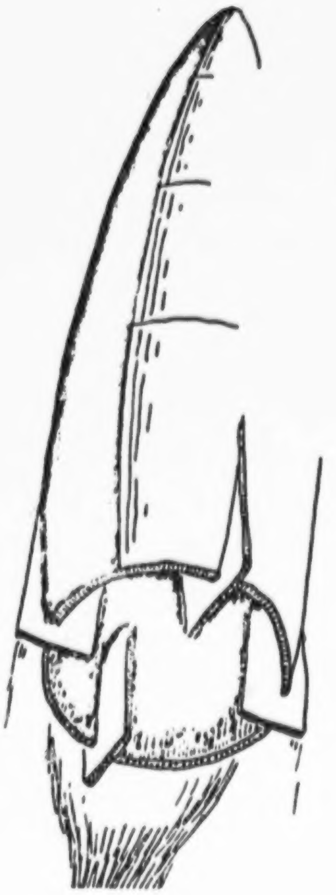




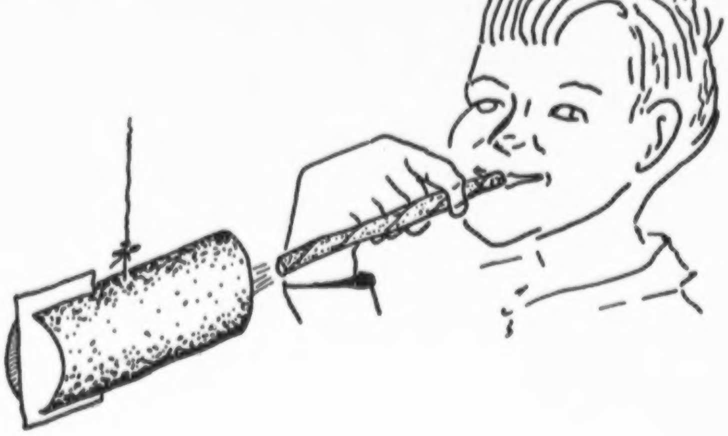
To control their flight while under power, most launch vehicles are provided with direction vanes. These are of various types. Some vehicles have aerodynamic vanes, which make the rocket change course by acting on the atmosphere as does the rudder of an airplane.

To understand how these fins work, cut out a model rocket from a file card, as shown in the illustration at the right. With a thread tied to its nose, slowly pull the model upward and observe its action. Bend the control surfaces and note the change in movement.

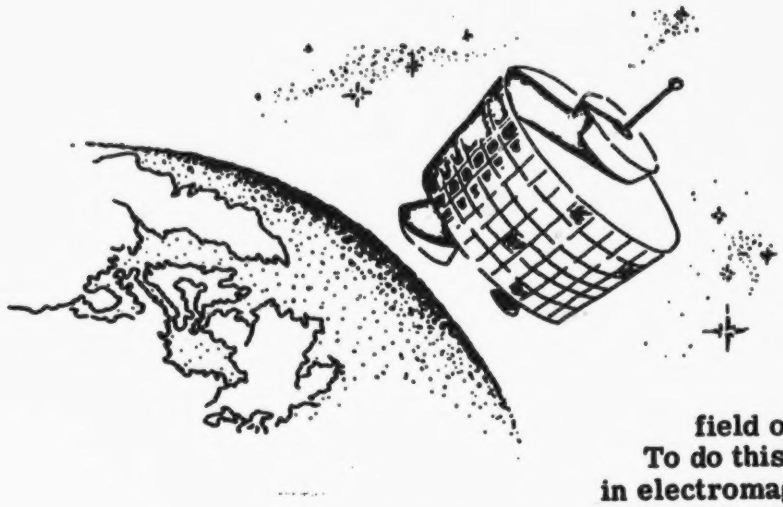
Among other types of direction vanes are those which, placed in the nozzle of the rocket, deflect the exhaust gases and thus force the craft to change course.



To see how this second type of guidance vane works, attach a small, verticle fin on the back of a cardboard tube, as shown in the diagram below. With a thread tied to a straight pin, hang the tube from its balancing point. Blow through it with a soda straw and notice how it changes position as the "guidance vane" deflects blown air.

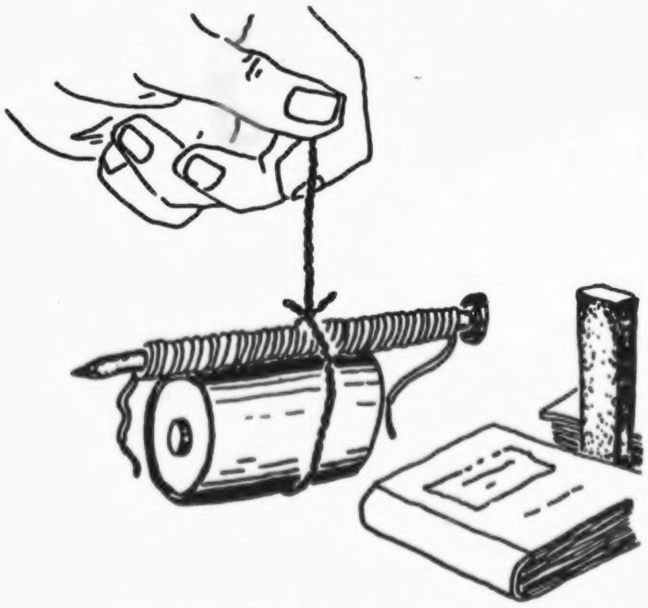


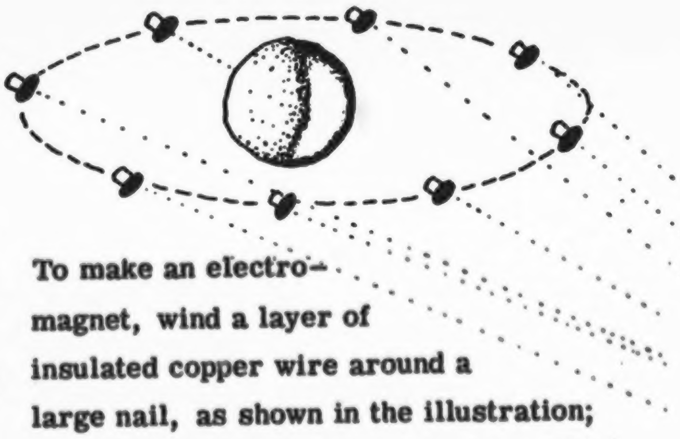
Reference: Haggerty, James J., Jr. Spacecraft. Washington, D. C.: National Science Teachers Assn., The National Education Assn., 1961.



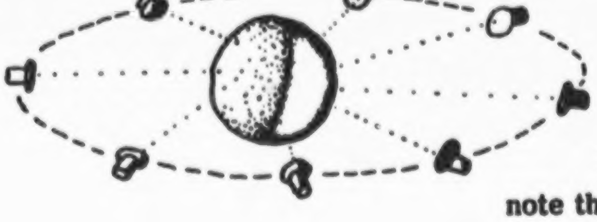
MAGNETIC CONTROL

While making observations or performing experiments related to the earth's surface, many man-made satellites use the magnetic field of the Earth for stabilization. To do this, the craft must have a built-in electromagnetic coil by which it can be controlled, changing altitude or direction. Because of the great distances involved, the interacting forces are weak. Nevertheless, this method of magnetic orientation is proving effective.





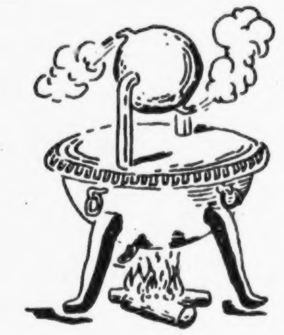
To make an electromagnet, wind a layer of insulated copper wire around a large nail, as shown in the illustration; tie a flashlight battery to its center with a string. Pass this unit around a permanent bar magnet held in a vertical position. Note that the unit's direction is affected very little by the magnetic field of the bar magnet (the Earth). It always points in one direction. This is called space oriented.

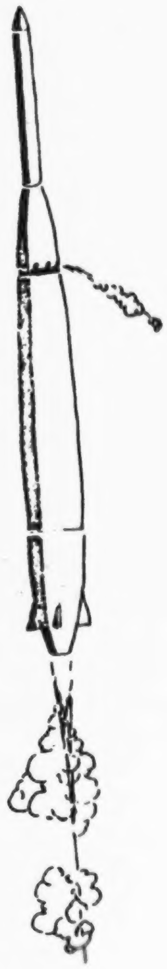


Connect the electromagnet wires to the battery with pieces of tape. Again make a pass around the bar magnet and note the change in the orientation of the unit.

Reference: Bender, Alfred. Let's Explore with the Electron. New York: Sentinel, 1960.

STEAM - AN ENERGY SOURCE IN SPACE -



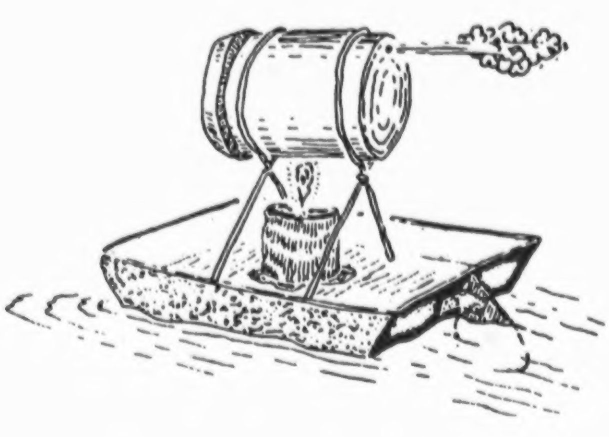


Steam was known in prehistoric times as clouds which were given off by hot springs. It was first used as a source of energy in 150 B. C., when Hero, a Greek philosopher, built a reaction turbine which rotated when steam ejected.

Today, the attitude controls of most spacecraft and the turbine pumps in rockets are powered by steam. In supplying the steam, small amounts of hydrogen peroxide are decomposed into water and oxygen with the liberation of heat. The heated water changes into steam, which is pressurized and ejected through small nozzles to produce the necessary action.

Steam can be defined as water, H O, changed into gas through heating. A molecule of H.O in any of its three forms— solid, liquid, or gas— looks the same. It is triangular, with the atoms at the three corners. In the solid form of ice, the molecules can only vibrate; as a liquid, they can rotate and vibrate. But in the form of steam they are free to move in any way. Since energy is implicit in movement, it follows that the molecules of steam have abundant energy. With high energy and ease of production, steam is an ideal source of specialized power in the space age.

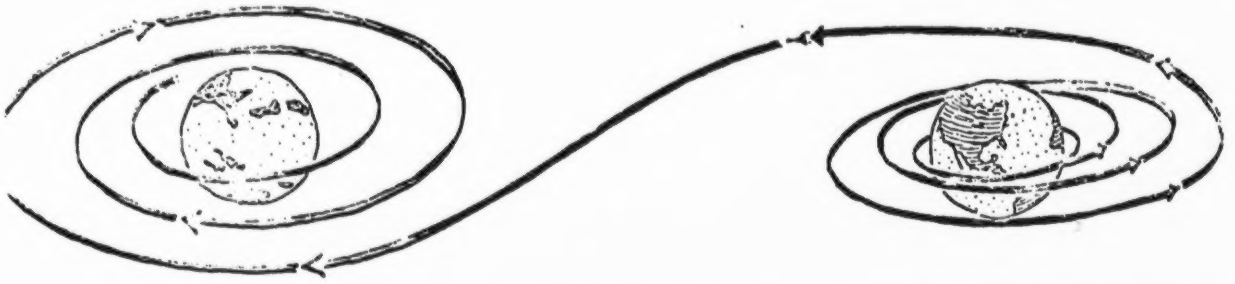
Make a small steam-reaction motor by punching a hole with a thin nail near one edge of the bottom of a 35mm film can or other small, sealable tin can (a shoe polish can will do very well). Rest the can on legs made from wire so that it will stand about four inches above the bottom of a plastic soap dish. Fill the can about one-quarter full of hot water, replace its cover, and stand it over a small candle in the soap dish. Place this "boat" in a pan of water and notice its motion as the jet of steam comes out of the hole in the can.



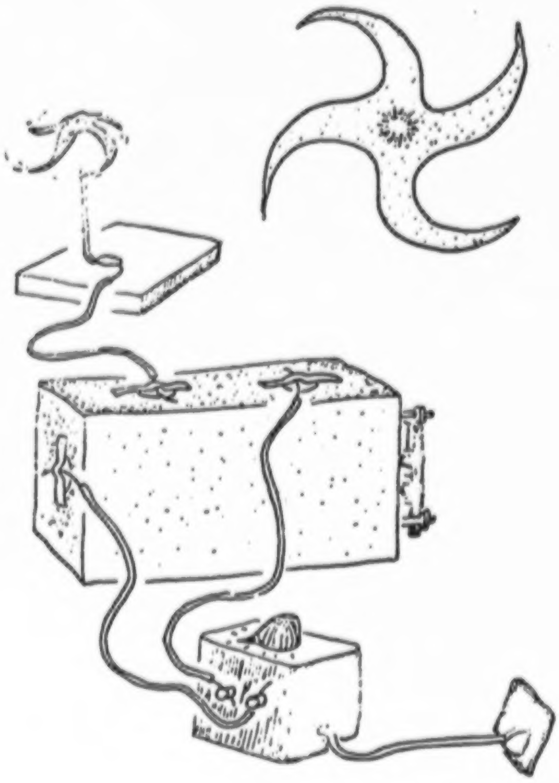
Reference: Miers, Earl S. The Storybook of Science. Chicago: Rand McNally, 1961.

FUEL OF THE FUTURE

Manned flights between planets are planned for this century, but there is much to learn about the techniques of space travel before they become a reality. A major problem has been the development of a rocket engine which would make more efficient use of fuel than does a chemical-burning or a nuclear engine. Space scientists have now developed an engine system which works by electric propulsion. In this system, electrostatically accelerated particles, traveling out of the exhaust nozzle of a rocket engine, would push a spaceship through space at tremendous velocities for long periods of time.



A trip to Mars is an example of the kind of space journey which might be undertaken with an electric propulsion engine system. Because of the great weight of the components, the spaceship would be assembled in an earth orbit and then proceed on its mission.

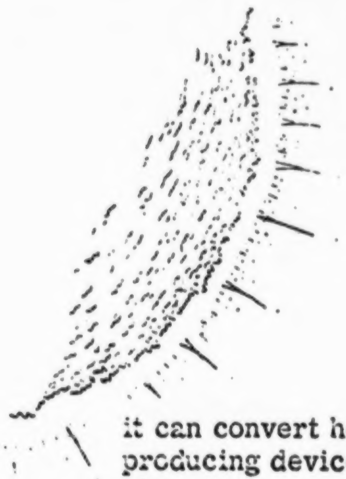


Place a small aluminum foil pinwheel at the top of a sharpened piece of wire and connect it to the "hot" terminal of an ignition spark coil. (This source of an electro-static force, designed for Model T Fords or Fordson tractors, can be obtained from most large auto supply stores.) Connect a toy train transformer or a battery with an output of about 6 volts, as shown in the diagram.

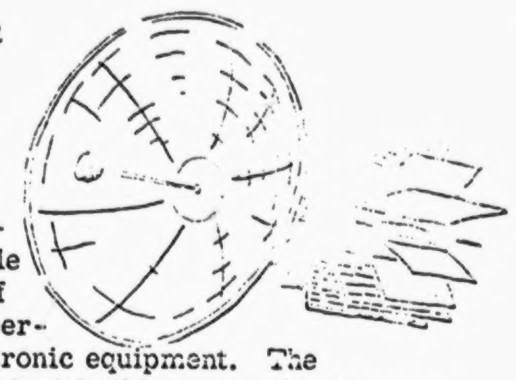
CAUTION - Never touch the terminals of the spark coil with your fingers when the power is on.

When the electrostatic force is activated, notice the action of the pin wheel.

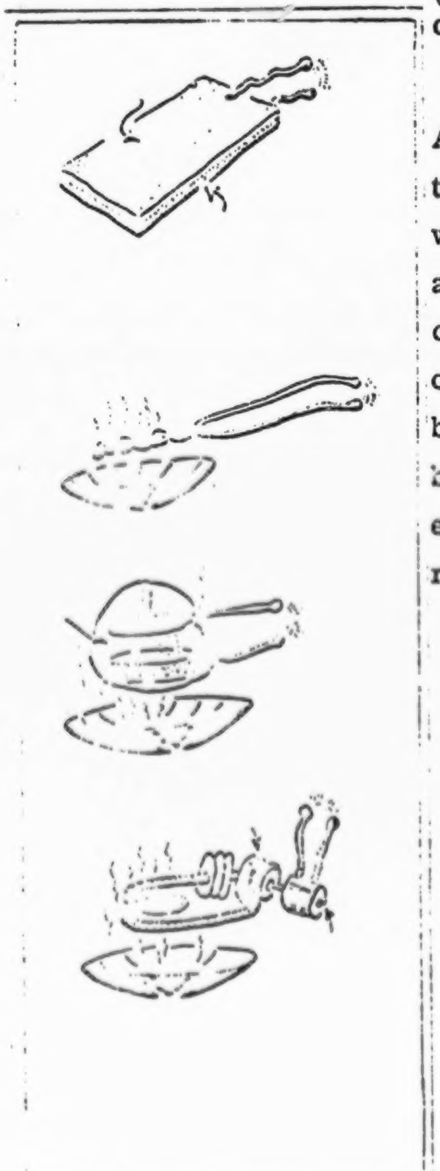
Reference: Mickelsen, William R. Space Flight Beyond the Moon. Cleveland: Lewis Research Center, 1962.



SPACE POWER SOURCES

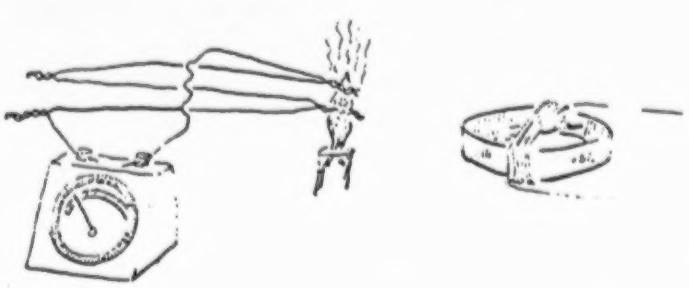


On long journeys through space, spacecraft require a reliable and efficient source of electrical power to operate the on-board electronic equipment. The thermocouple is important in this connection because it can convert heat energy from the sun or from a simple, nuclear heat-producing device directly into usable electrical energy. This heat-to-electricity conversion is one of the many types of generating systems (see illustrations at left) being developed for spacecraft of the future.



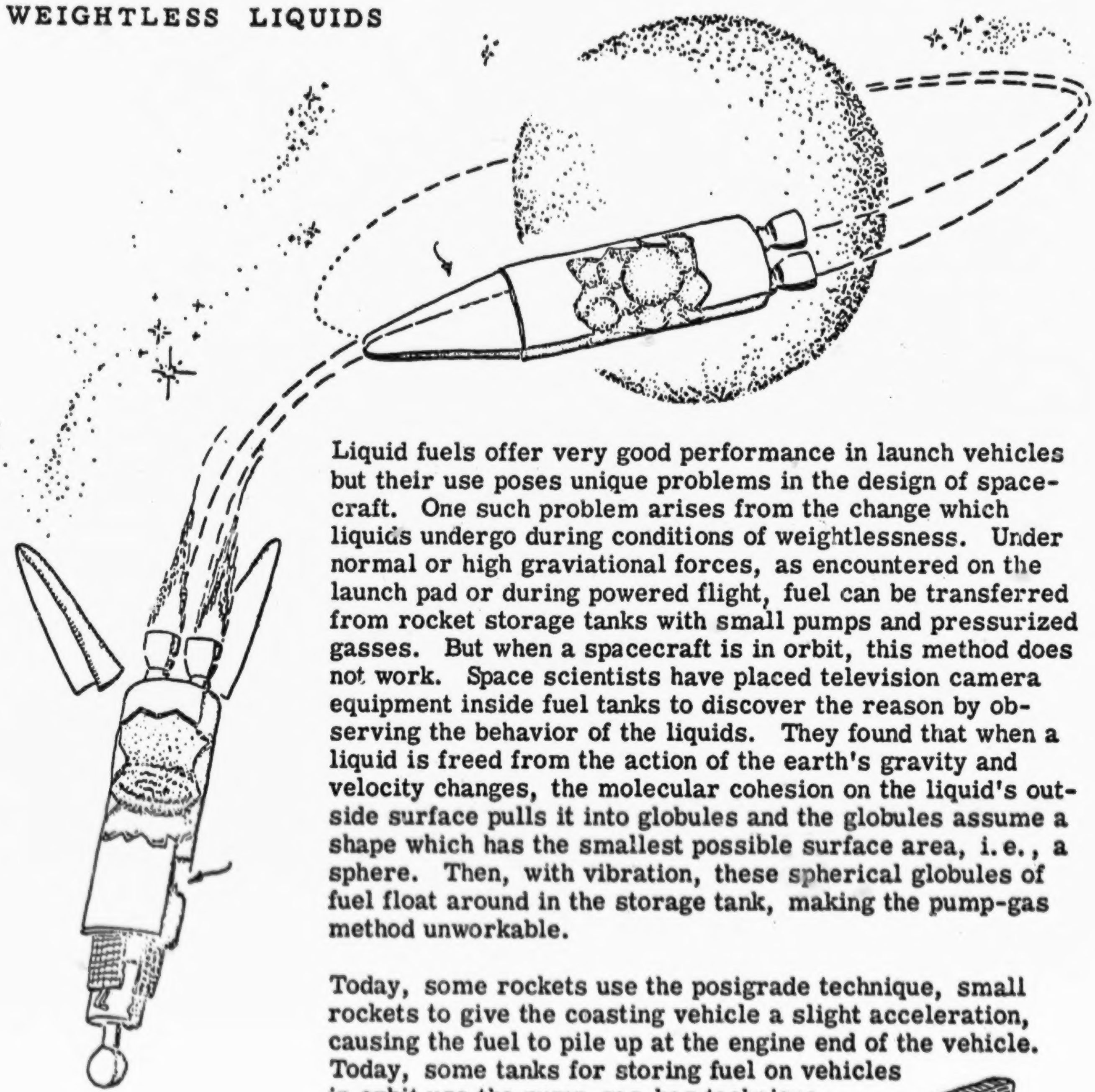
A simple thermocouple can be made by twisting together the ends of a few pieces of copper and iron wire of equal thickness. Be sure the ends of the wires are clean and the junctions are tight. Then, heat the copper-iron junctions at one side while those at the other side are kept cool, as shown in the illustration below. This produces a flow of electricity which can be measured by a sensitive galvanometer. A more efficient system can be made by using constantan rather than iron wire.

A simple galvanometer can be made by winding fine, insulated wire many times around a sensitive compass.



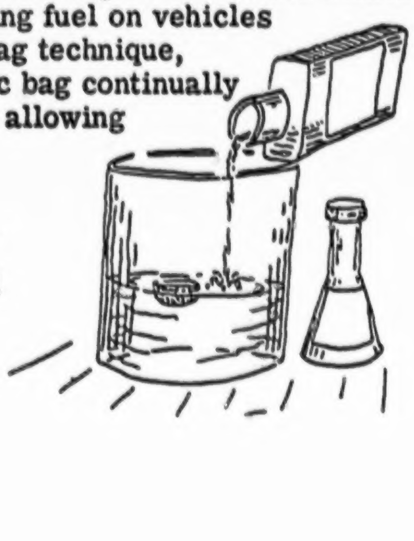
Reference: Foster, Ronald M. Jr., editor. Satellite Communication Physics.

WEIGHTLESS LIQUIDS



Liquid fuels offer very good performance in launch vehicles but their use poses unique problems in the design of spacecraft. One such problem arises from the change which liquids undergo during conditions of weightlessness. Under normal or high graviational forces, as encountered on the launch pad or during powered flight, fuel can be transferred from rocket storage tanks with small pumps and pressurized gasses. But when a spacecraft is in orbit, this method does not work. Space scientists have placed television camera equipment inside fuel tanks to discover the reason by observing the behavior of the liquids. They found that when a liquid is freed from the action of the earth's gravity and velocity changes, the molecular cohesion on the liquid's outside surface pulls it into globules and the globules assume a shape which has the smallest possible surface area, i.e., a sphere. Then, with vibration, these spherical globules of fuel float around in the storage tank, making the pump-gas method unworkable.

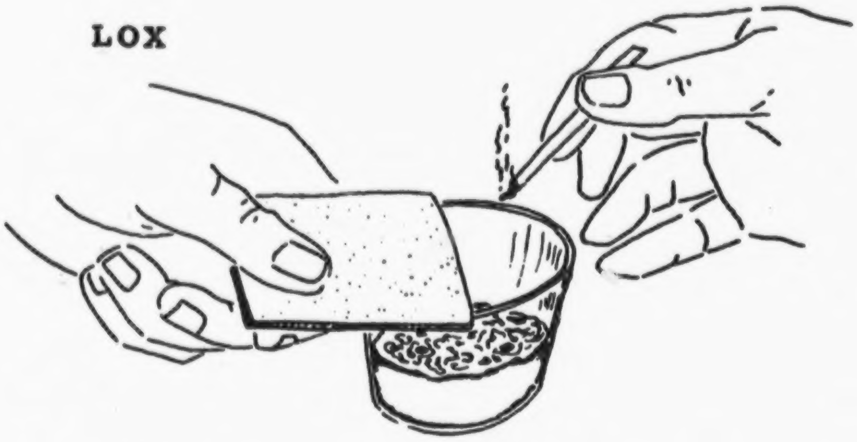
Today, some rockets use the posigrade technique, small rockets to give the coasting vehicle a slight acceleration, causing the fuel to pile up at the engine end of the vehicle. Today, some tanks for storing fuel on vehicles in orbit use the pump-gas-bag technique, whereby a collapsible plastic bag continually presses the fuel in the direction of the pumps, thus never allowing the liquid to break up into separate globules.

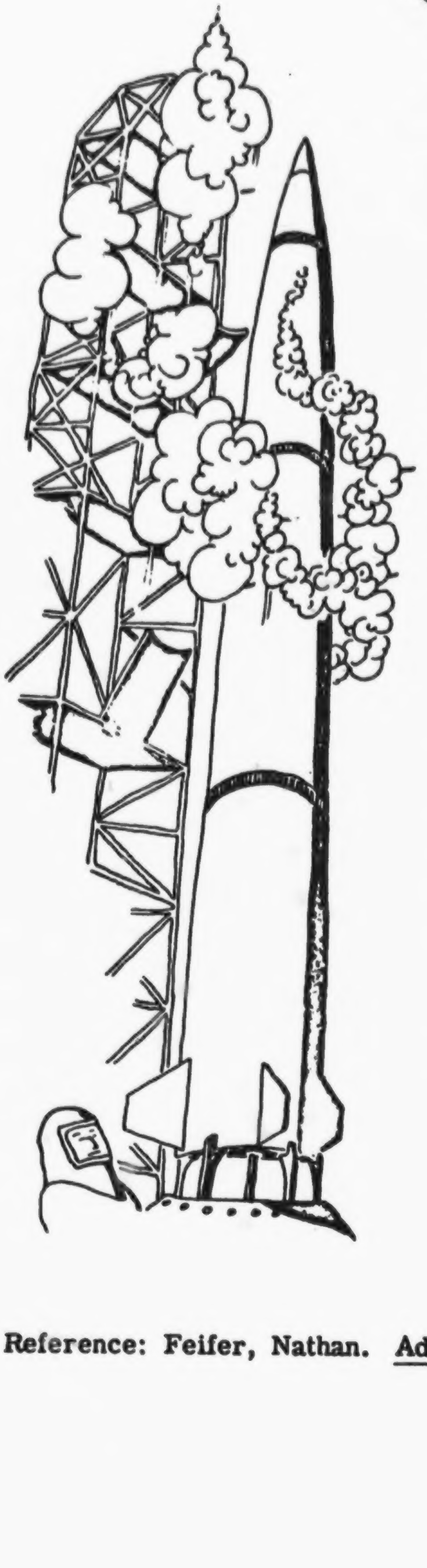


Place a drop of olive oil on two inches of water in a clear glass jar. Slowly add some rubbing alcohol. The oil will sink until it floats beneath the surface in a state of weightlessness. Notice the shape that it assumes. Break the oil drop by striking it with a spoon and observe the shape of each of the globules.

Reference: Clark, Arthur C. The Exploration of Space. New York: Harpers, 1959.

LOX





In his early experiments with liquid fuels for launch vehicles, Dr. Robert Goddard found that burning the fuel alone, in air, does not provide the required action. An oxidizer is needed to increase the burning rate— or action—and thus provide greater reaction. Liquid oxygen (LOX) is the oxidizer mixed with a refined kerosene, called RP-1, commonly used in the present launch vehicles. For the mixture, gaseous oxygen is liquified by reducing its temperature to about 300 degrees Fahrenheit below zero.

Pour about one inch of common hydrogen peroxide into a drinking glass and add a small amount of manganese dioxide (the black powder from the inside of an old flashlight battery). Place a piece of cardboard over the top and notice the bubbles that escape from the peroxide. They are bubbles of oxygen gas. Light a broom straw or long wooden splinter. Blow out the flame. Put the glowing straw or splinter into the gas and notice how the oxygen affects the action.

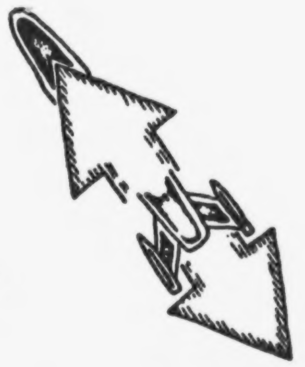
Reference: Feifer, Nathan. Adventures in Chemistry. New York: Sentinel, 1959.

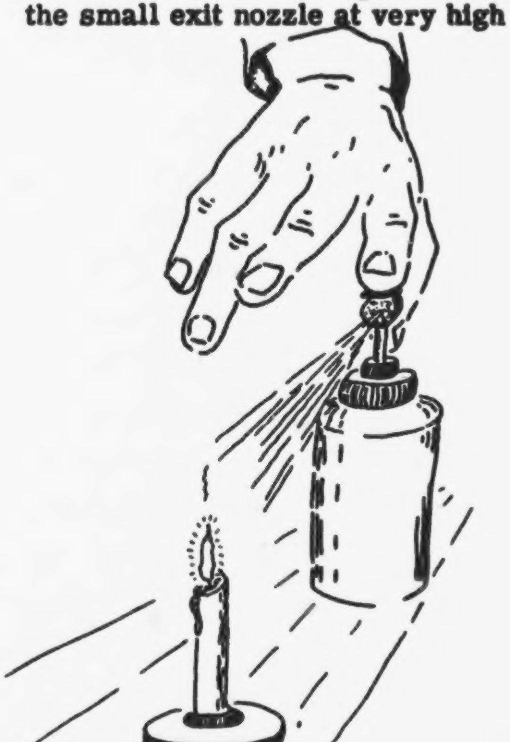
RP - I

Scientists believe that petroleum, or "rock oil," was formed from plants and animals that lived ages ago in and around warm areas that covered much of the earth. Petroleum is one of the greatest servants of mankind. Without it as a lubricant, most of the world's machines would grind to a stop. It provides light, heat, and power.

In its crude form, as taken from the well, petroleum is of little use because of its impurities. By applying heat, however, it is refined and broken down into its various parts.

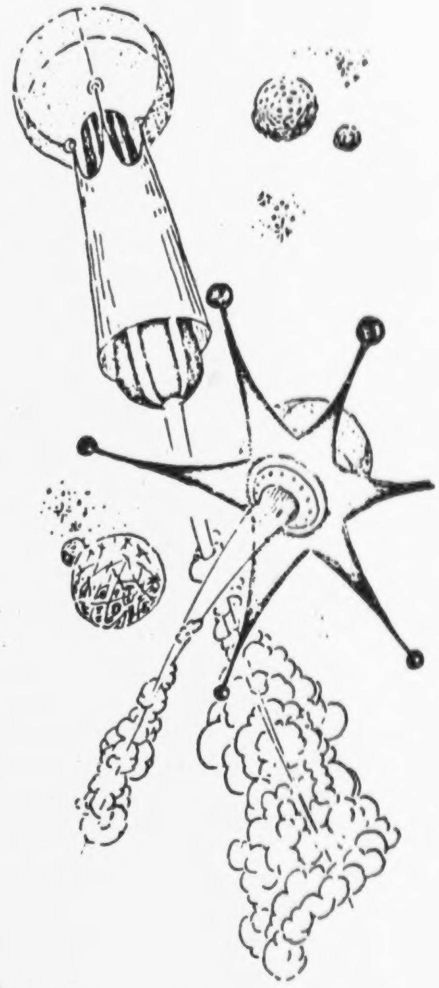
Kerosene produced from petroleum and purified by a filtering process is used as the fuel in many of the liquid-fueled rockets. It is called Rocket Propulsion Number One, or RP-1. When a rocket is fired, RP-1 and LOX (Liquid Oxygen) are compressed and forced into the combustion chamber, where the mixture is ignited. Once ignited, it burns continuously. This combustion causes the gases to expand and rush out the small exit nozzle at very high speeds. Reaction to the force of the flow of gases thrusts the rocket forward.





Spray a small amount of rubbing alcohol over the top of a candle flame with a spray atomizer. As the rubbing alcohol-air mixture (RP-1-LOX) ignites, notice the burning pattern and the amount of heat and expansion produced over a short period of time. Compare the length of burning time with that of an equal amount sprayed into a metal bottle cap and then burned. **CAUTION: STAND AWAY FROM THE CANDLE FLAME AND FROM THE SPRAY.**

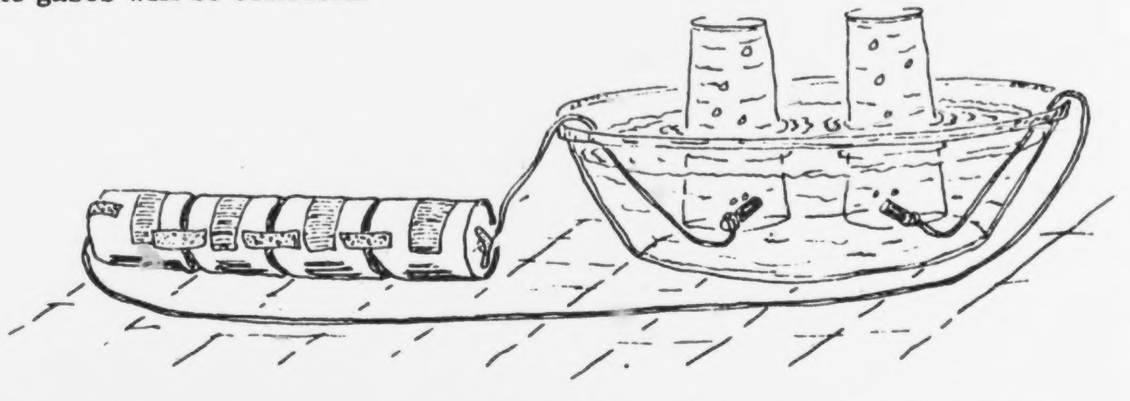
Reference: Blackwood, Paul. Push and Pull: The Story of Energy. New York: McGraw-Hill, 1957.



SUPER ROCKET FUEL

Whenever you drink a glass of water, you swallow the components of a powerful chemical rocket fuel. Water, a heavy, liquid substance which can be easily felt and seen, is composed of two invisible gases called oxygen and hydrogen. The chemical combination of these gases yields more thrust per pound of fuel than any other substance. Because of the theoretical abundance of water in the universe and the ease with which it can be broken apart, water makes an ideal fuel for extended space journeys.

Four flashlight batteries will give the required amount of electricity to break a small amount of water apart into the two gases, hydrogen and oxygen. Take the carbon rod from the middle of an old flashlight cell, break it in half to make two electrodes. Remove the insulation from the ends of two pieces of insulated copper wire and attach one to each electrode. Dissolve a tablespoon of washing soda in a large bowl of water (this makes the water a good conductor of electricity); fill the two drinking glasses with a similar solution and invert them in the bowl. Slip a carbon electrode up into each of the two glasses and attach the other ends of the wires to the batteries. Notice that bubbles begin to collect in the glasses—about twice as fast in one as in the other. Because of the limited amount of electricity used, only a small amount of the gases will be collected.

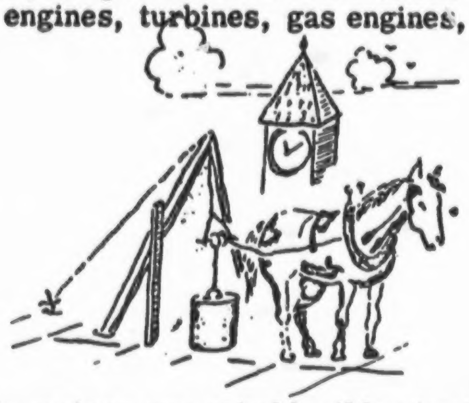


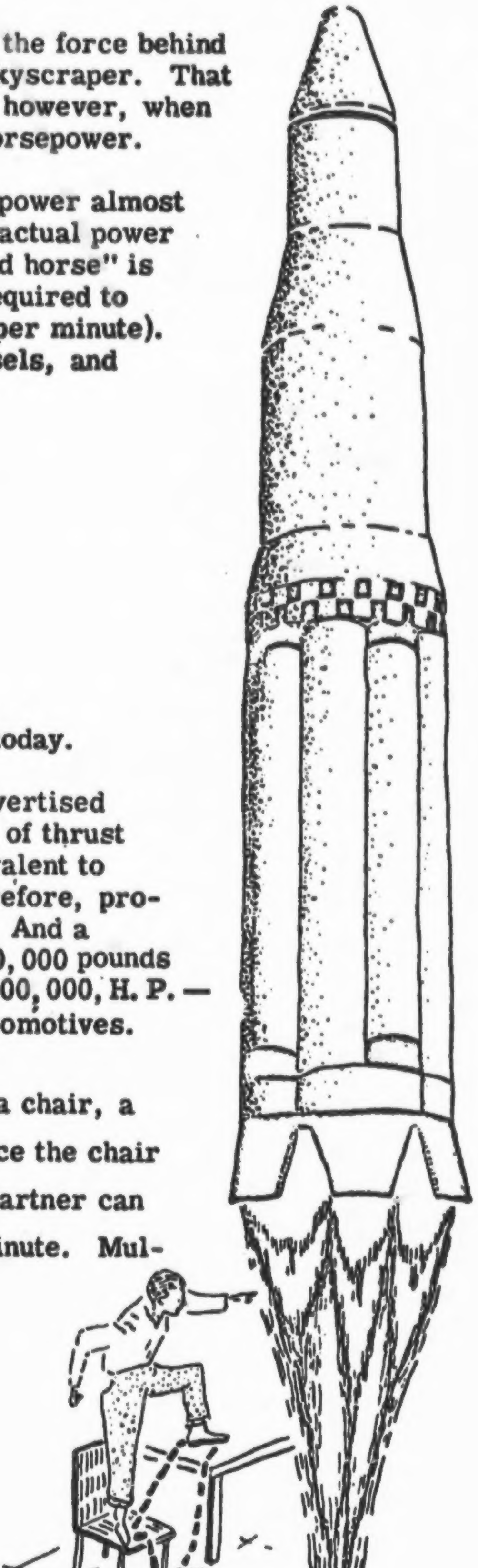
Reference: Brent, Robert. The Golden Book of Chemistry Experiments. New York: Golden Press, 1960.

THRUST AT LIFT-OFF

To the novice, it is difficult to comprehend the force behind power which can launch a rocket tall as a skyscraper. That power--thrust--can be readily understood, however, when it is converted into the common rating of horsepower.

James Watt introduced the concept of horsepower almost two centuries ago. According to Watt, the actual power delivered for useful work by a "standardized horse" is 33,000 foot-pounds per minute (the force required to raise 33,000 pounds at the rate of one foot per minute). Steam engines, turbines, gas engines, Diesels, and electric motors are rated by this standard today.



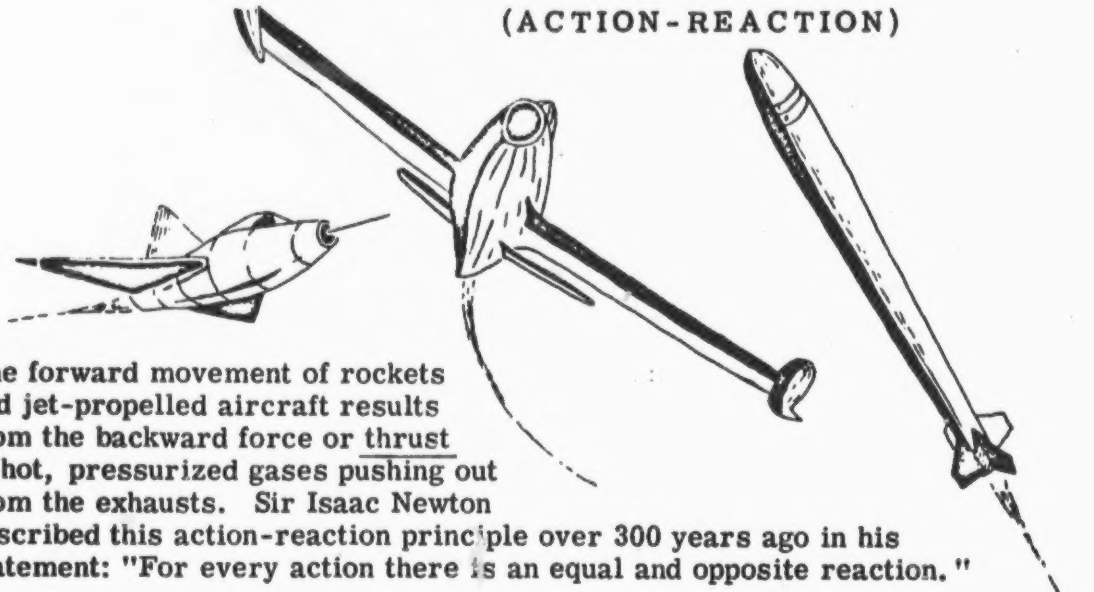


An average American automobile has an advertised horsepower rating of about 200. One pound of thrust from a rocket motor is approximately equivalent to 20 horsepower. The 200 H.P. engine, therefore, produces the equivalent of 10 pounds of thrust. And a rocket the size of Saturn 1, developing 1,500,000 pounds of thrust, theoretically produces about 30,000,000 H.P. — the total rating of 5000 average railroad locomotives.

Human horsepower can be determined with a chair, a ruler, a watch, and a bathroom scale. Place the chair next the table and count how many times a partner can step from the floor to the table top in 1/4 minute. Multiply the height of the table (in feet) by the weight of the person; multiply the product by the number of trips which could be made in a minute; divide the second product by 33,000.

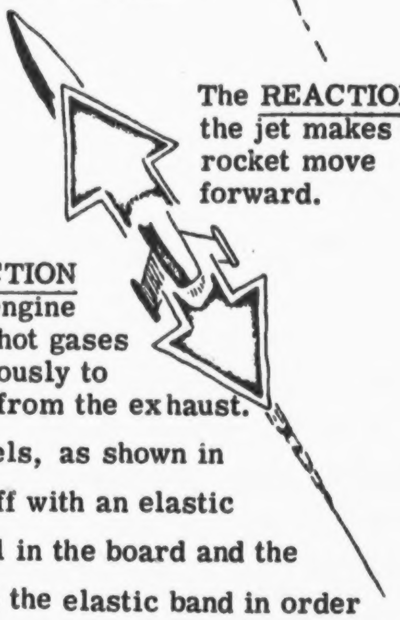
Reference: Public Relations Staff, General Motors. The Story of Power. Detroit: General Motors, 1956.

THRUST
(ACTION-REACTION)



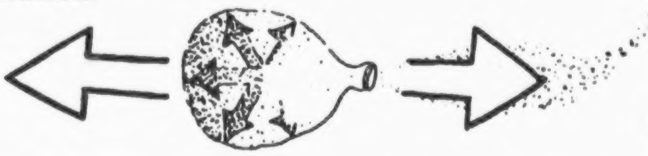
The forward movement of rockets and jet-propelled aircraft results from the backward force or thrust of hot, pressurized gases pushing out from the exhausts. Sir Isaac Newton described this action-reaction principle over 300 years ago in his statement: "For every action there is an equal and opposite reaction."

The action-reaction principle is demonstrated when the arm and hand of the marksman are jerked backward as the bullet ejects forward from the gun. Thrust is demonstrated when a balloon streaks away as the air gushes out of its nozzle. In rockets and jet-propelled aircraft, the principle is in continuous operation.

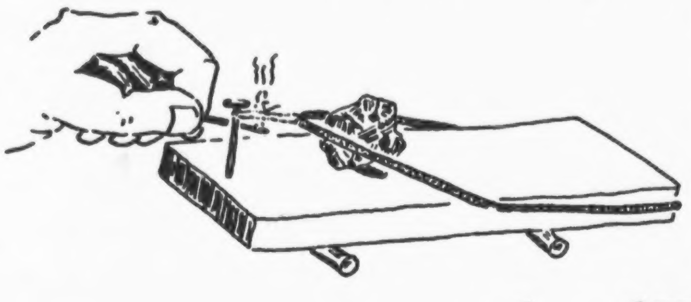


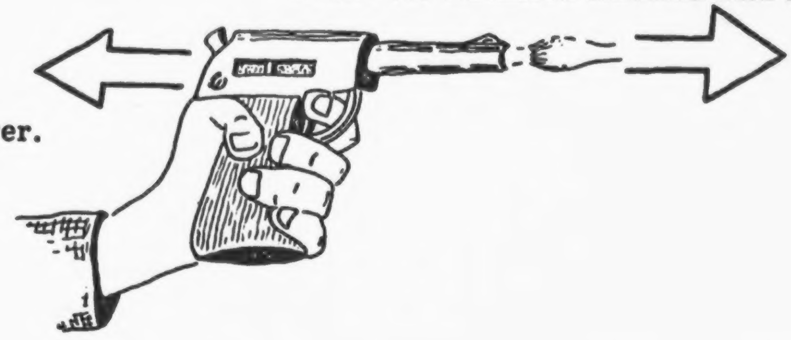
The REACTION to the jet makes the rocket move forward.

The ACTION of the engine forces hot gases continuously to jet out from the exhaust.

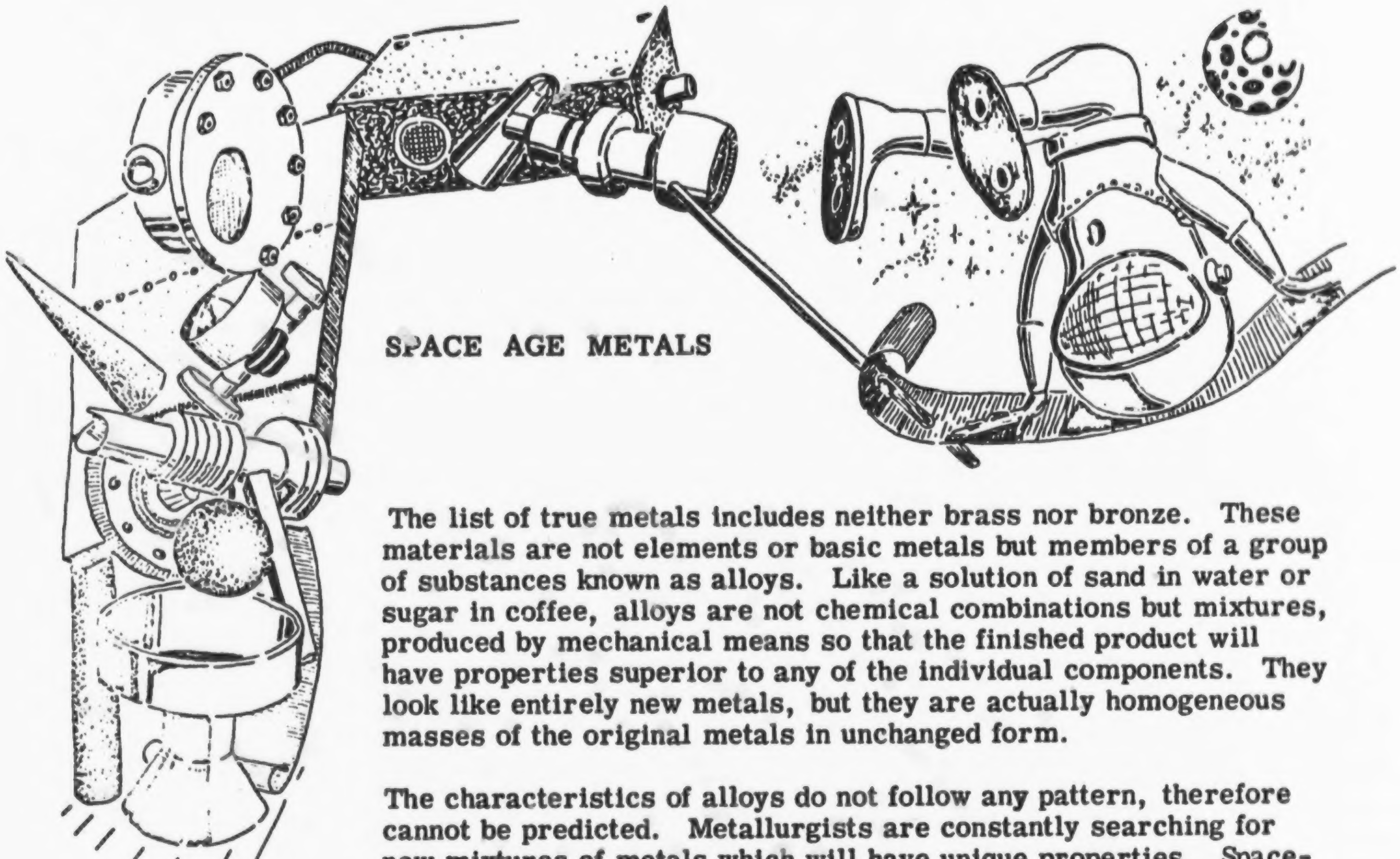


Place a stone on a small board, which rests on two dowels, as shown in the diagram below, so that the stone can be catapulted off with an elastic band. Attach one end of a short length of string to a nail in the board and the other end to the elastic band in order to provide tension. Use a match to burn through the string, thus releasing the tension and the power of the elastic band. The board will move, rolling on the dowels. Notice the distances traveled with different-sized weights and different amounts of power.





Reference: General Motors. A Power Primer. Detroit: General Motors, 1955.

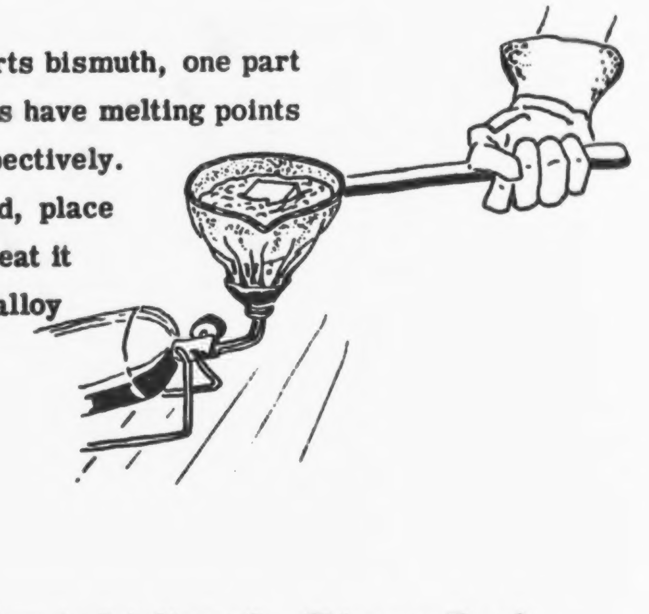


SPACE AGE METALS

The list of true metals includes neither brass nor bronze. These materials are not elements or basic metals but members of a group of substances known as alloys. Like a solution of sand in water or sugar in coffee, alloys are not chemical combinations but mixtures, produced by mechanical means so that the finished product will have properties superior to any of the individual components. They look like entirely new metals, but they are actually homogeneous masses of the original metals in unchanged form.

The characteristics of alloys do not follow any pattern, therefore cannot be predicted. Metallurgists are constantly searching for new mixtures of metals which will have unique properties. Space-age technology, for instance, requires materials with great toughness, conductivity, and pliability. The metal scientists have already produced ferro-aluminum, manganese steel, invar (iron, nickel, and carbon), Monel metal (nickel, copper, and iron), and Rene 41. The latter alloy, used for the covering of the Mercury capsules, is a good example of a material particularly useful in the space program. Composed of nickel and cobalt, it can withstand higher temperatures and transmit heat faster than can either of its parts.

Make a mixture which by weight is two parts bismuth, one part tin, and one part molten lead. The metals have melting points of 271 , 232 , and 327 Centigrade, respectively. After the mixture cools and becomes hard, place it in a container with water to cover and heat it to the boiling point. This has become an alloy known as Rose's Alloy. Notice its most curious and important property during the heating process.



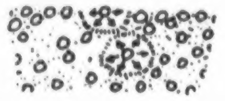
Reference: May, Julian. There's Adventure in Jet Aircraft. Chicago: Popular Mechanics Press, 1959.

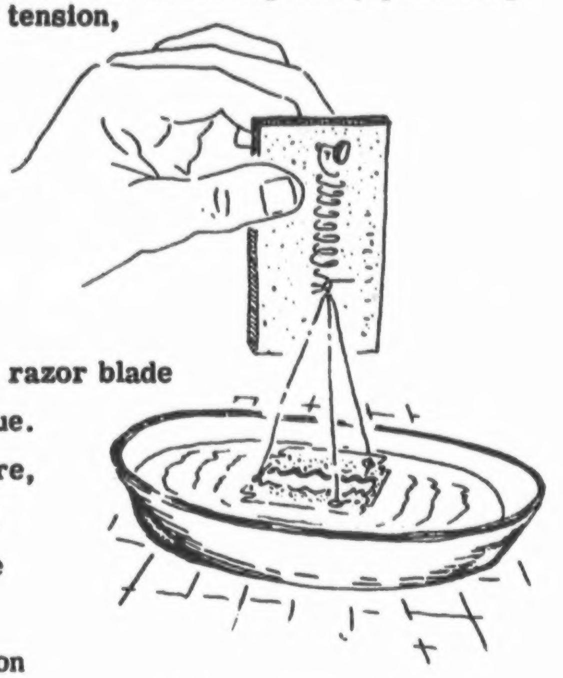
MATERIAL SURFACES

A surface-to-surface meeting of many materials, particularly in the vacuum of space, results in phenomena which do not occur in the materials left separated. The metal surfaces of two spacecraft meeting in a space rendezvous, for instance, would probably weld together if their surfaces were not treated with a separating compound. And the axles of turbine fuel pumps would not function properly if they were not lubricated or separated by some other material with low friction characteristics.

Mechanical astro-engineers, therefore, are vitally interested in the effect of the contact between materials of all kinds. They are concerned, further, with exposed surfaces generally and are using various coatings—wax, paint, and thin metal—to protect surfaces from contact with other surfaces and from atmospheric elements, solar radiation and the hard vacuum of space.

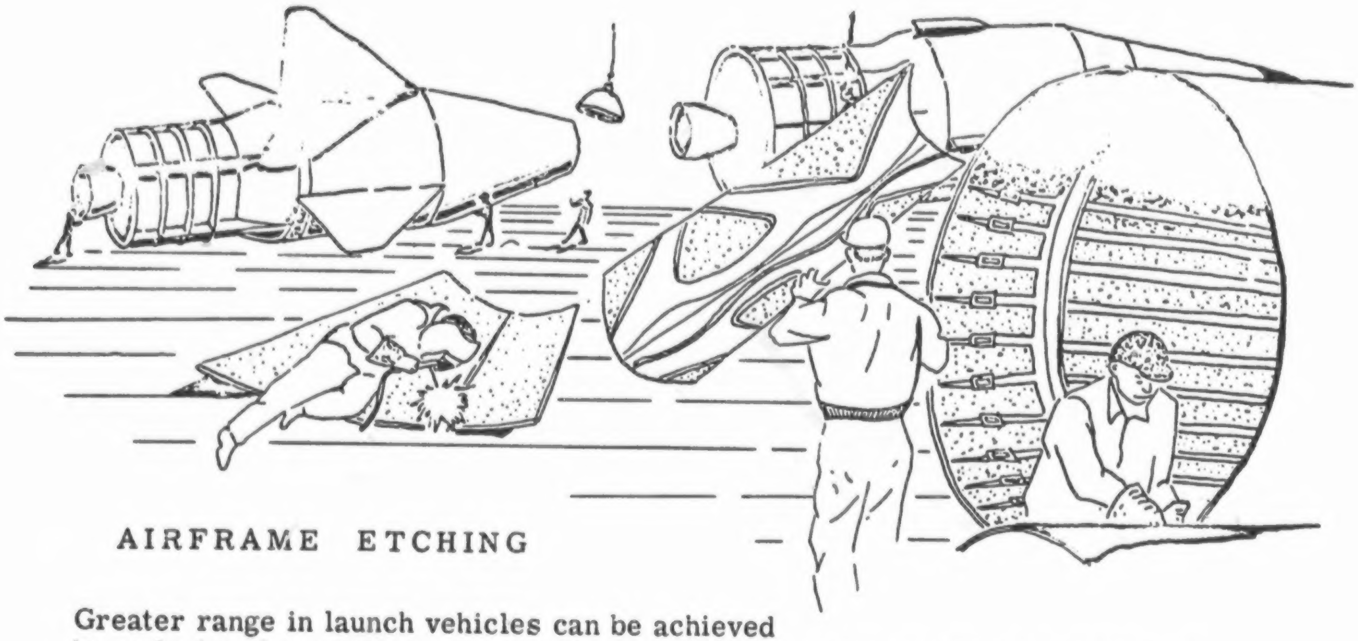
The reason for their concern is this: Inside the mass of any material, the molecular forces are in equilibrium because each molecule is entirely surrounded by others. But molecules at the surface are affected only by the molecules beneath them. This uneven attraction results in pulling the surface molecules closer together, producing a phenomenon called "surface tension." Surface tension, however, is disturbed in the encounter between surfaces of various materials.





A comparative measurement of the molecular attraction of liquid surfaces can be made with the apparatus shown at the right. Attach a clean razor blade to three pieces of thread, with small drops of glue. Make a light spring with a dozen turns of fine wire, twisting the lower end to serve as a pointer, and attach it by a nail to a piece of wood. Attach the threads to the spring and record the resting place of the pointer. Lower the razor squarely on the surface of the liquid; then raise it and note the amount of deflection indicated by the pointer. Note the difference in surface tension with different liquids such as water, oil, alcohol, etc.

Reference: Mehrens, H. E. The Dawning Space Age. Ellington Air Force Base, Texas: Civil Air Patrol, 1959.

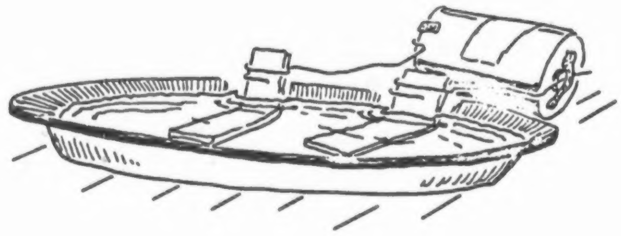


AIRFRAME ETCHING

Greater range in launch vehicles can be achieved by reducing the vehicle's weight. One way to reduce the weight is to design the rocket shell to serve as its own fuel tank, thus eliminating separate fuel storage containers. Another method is through the use of light weight, high strength structural materials such as aluminum, nickel, and magnesium alloys, sheet and foam plastics, and fiber glass.

To achieve maximum weight reduction, patterns are usually etched into the structural material by a chemical or mechanical process. The etching of these patterns, which have been carefully tested, also results in making many materials even stronger.

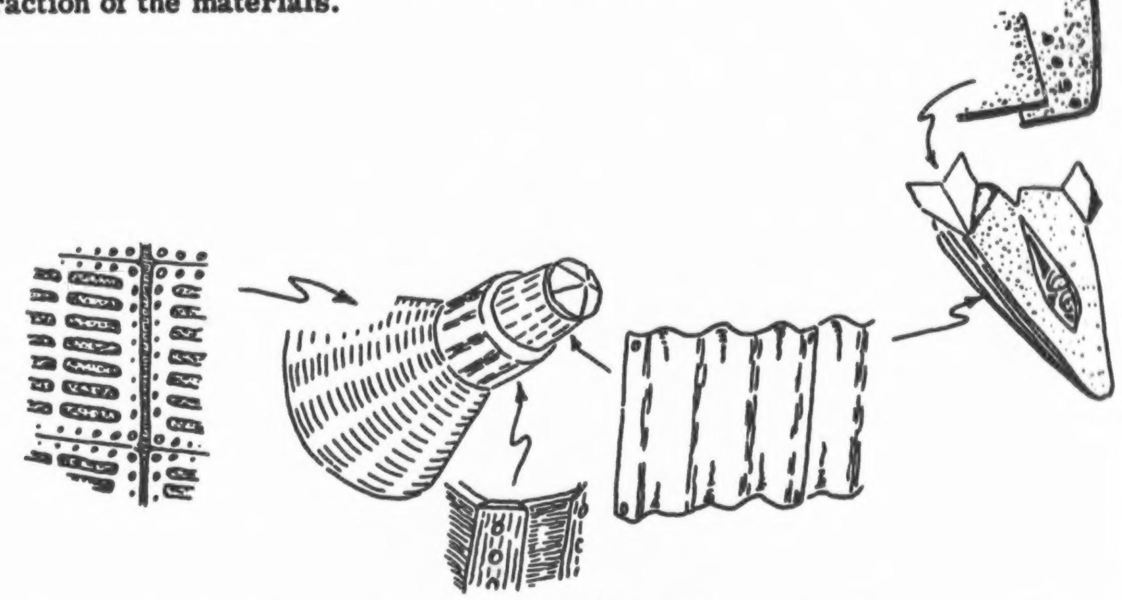
To experience the way etching works, attach two wires to two copper strips, bent as shown in the diagram below. Dip one of the strips into melted paraffin wax. Scrape a design into the soft wax down to the bare metal. Connect the wires to a flashlight battery and let stand overnight in a solution of ordinary table salt and water. Bubbles forming on the copper will indicate that the etching process is taking place. Remove the wax with hot water and note the finished etching.



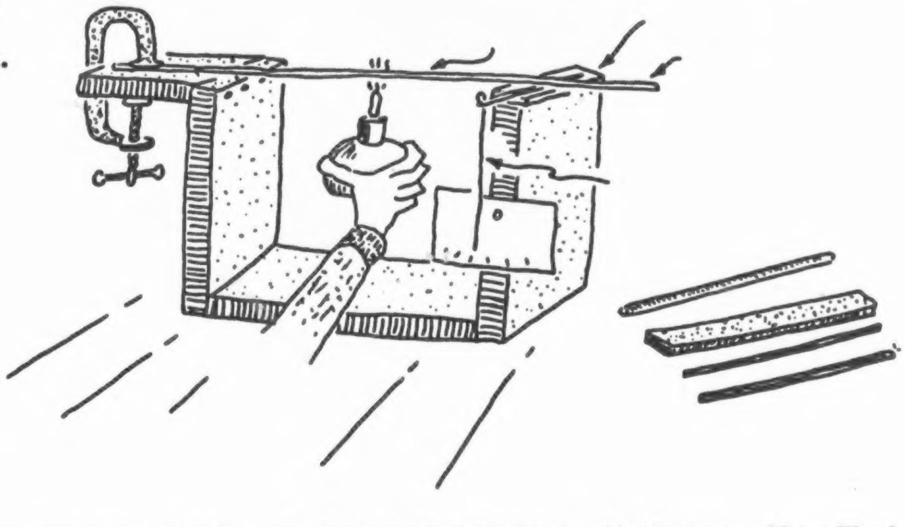
SPACECRAFT SKIN

Spacecraft destined to make long space journeys and to return to earth will face difficulties more formidable than any ever encountered by aircraft. Among the most hazardous of the difficulties are temperatures ranging from 4,000 F. in space to 15,000 F. during reentry. Spacecraft designers, therefore, are constantly searching for materials and construction techniques which can withstand these extremely high temperature conditions.

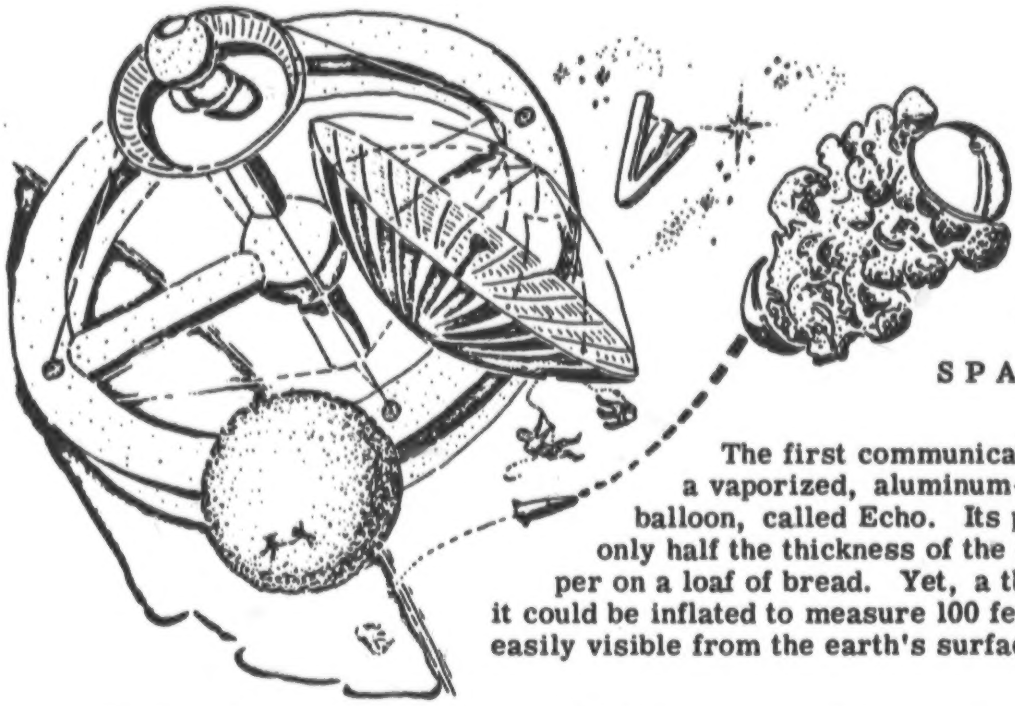
Examples of effective structural designs already in use include the overlapping of metal shingles on the neck of the Mercury capsule and corrugations in the skins of some of the more advanced craft. These permit scale-like and accordion-like movements when temperature changes result in expansion and contraction of the materials.



Set up an apparatus as shown below, using a wooden frame, a microscope slide, "C" clamp, needle and pointer, and a candle or alcohol lamp. Clamp various metals on this test stand and notice how they expand and contract to varying extents when heated or cooled. Try different thicknesses and widths of flat stock and of round and tube stock.



Reference: Asimov, Isaac. Building Blocks of the Universe. New York: Abelard-Schuman, 1961.

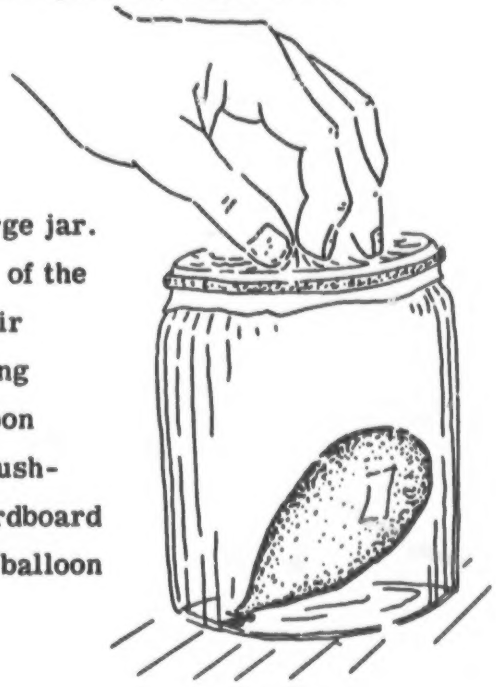


INFLATABLE SPACECRAFT

The first communication satellite was a vaporized, aluminum-coated, plastic balloon, called Echo. Its plastic wall was only half the thickness of the cellophane wrapper on a loaf of bread. Yet, a thousand miles up, it could be inflated to measure 100 feet across and was easily visible from the earth's surface by the naked eye.

Balloon-type spacecraft can be inflated with very little gas pressure, as was Echo, because of the relatively limited atmospheric pressure in space. Further, the lack of pressure from the outside allows the craft to stay inflated with very little pressure from the inside. These facts have led to the proposal that balloon-like designs be developed for the construction of a variety of orbiting vehicles--manned space stations, solar reflectors, antenna systems, and others.

To experience the way limited exterior pressure allows relatively little interior pressure to maintain inflation, place a small balloon, partially inflated and tied, inside a large jar. Cut another, larger balloon in half and pull one of the halves over the mouth of the jar. Lessen the air pressure inside the jar by pulling up the covering balloon-half at its center. Notice that the balloon inside the jar expands. Follow this action by pushing down on the covering balloon-half with a cardboard disk. Notice the difference in the action of the balloon within the jar.



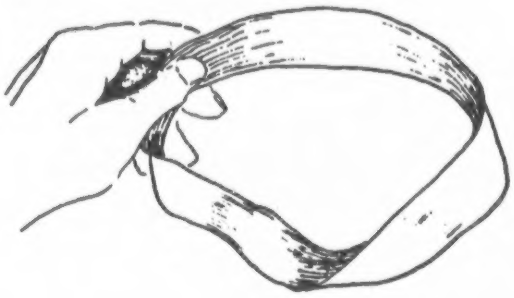
Reference: Burgess, Eric. Satellites and Spaceflight. New York: Macmillan, 1957.

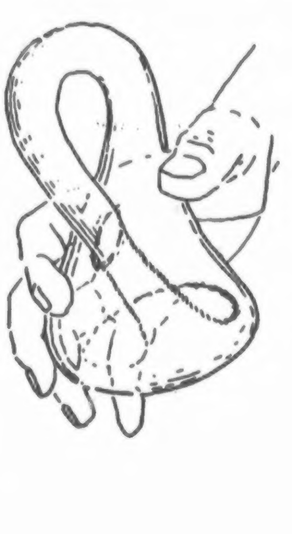
SPACE-AGE SHAPES

Topology, one of the newest, most exciting, and least known branches of geometry, is an area of modern mathematics increasingly employed in other sciences. It is useful in designing the intricate electronic networks of spacecraft and their support equipment. It is employed in chemistry to study the linkages of isomeric compounds and their properties and may thus lead to the future production of better structural materials and fuels. Topological concepts are being used also to study conflicting elements in economics and even behavior patterns in psychology and sociology. Further insight into the abstractions of topology will undoubtedly lead to the discovery of many useful devices.

Topology makes feasible shapes and surfaces hitherto regarded as impossible. A Moebius strip, for instance, has only one side and edge. This topological surface is used in spacecraft today for printed circuits whose components must not cross any other components at any point.

Another topological shape, the Klein bottle, like the Moebius strip has only one surface and the additional characteristics that the surface is sphere-like, completely closed, with no inside or outside, and no edges. Intricate equipment can be solidly packed in this configuration and yet all parts will be accessible. Cut in half, a Klein bottle makes two Moebius strips, each an exact duplicate of the other.

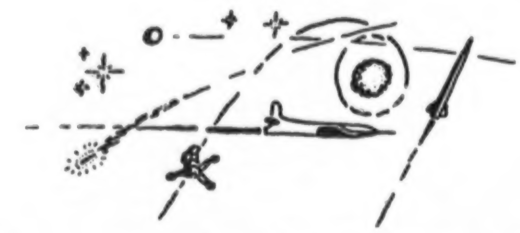




A Moebius strip can be made by cutting out a strip of newspaper, giving it a half-twist, and pasting the two ends together. Draw a pencil line over its flat surface until the end of the line joins the beginning. This will illustrate that the strip has one side and one edge. Try to color completely one side and not the other. This will be impossible because the strip has no other side.

Now cut the Moebius strip down its center, exactly in half. Cut one of the halves again, along a line dividing it into one-third and two-thirds. Note the results.

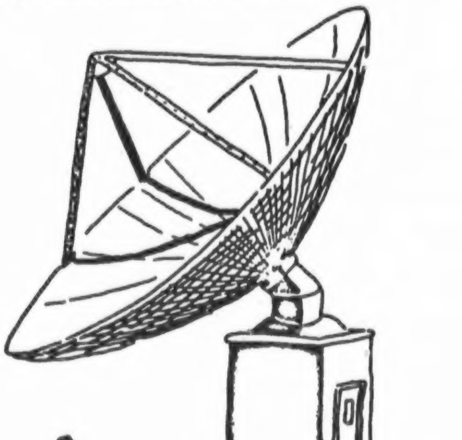
Make another Moebius strip and give it more twists before you glue it together. Cut it, as before, and note the results.

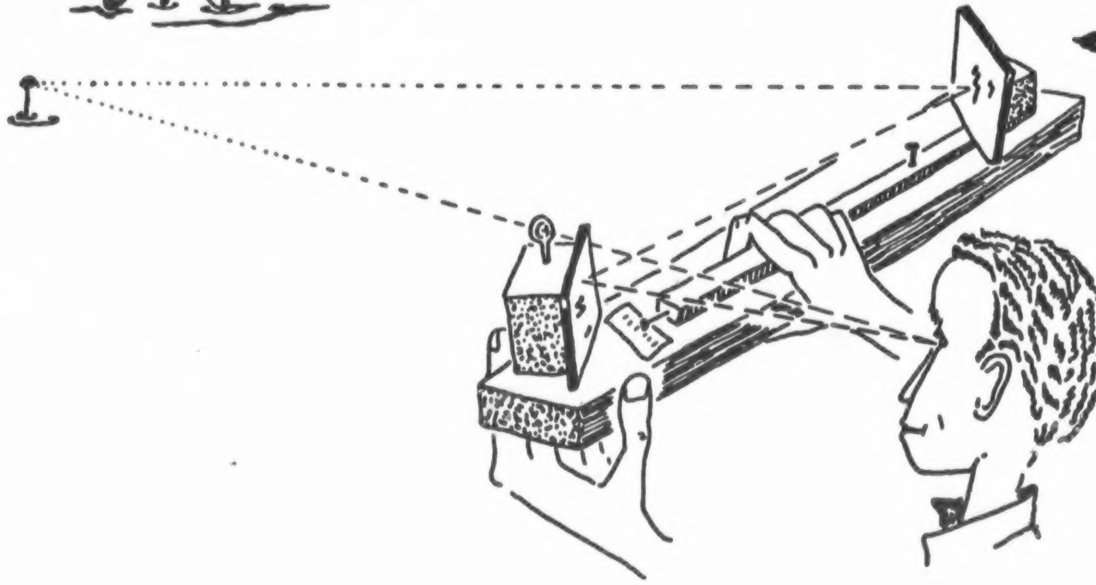


RANGE FINDING

To carry out high altitude research on wind currents (sodium vapor clouds), air density (upper explosions), the auroral phenomenon (Northern Lights), and satellite and space-probe locations, many kinds of elaborate optical and electronic distance-determining equipment are used.

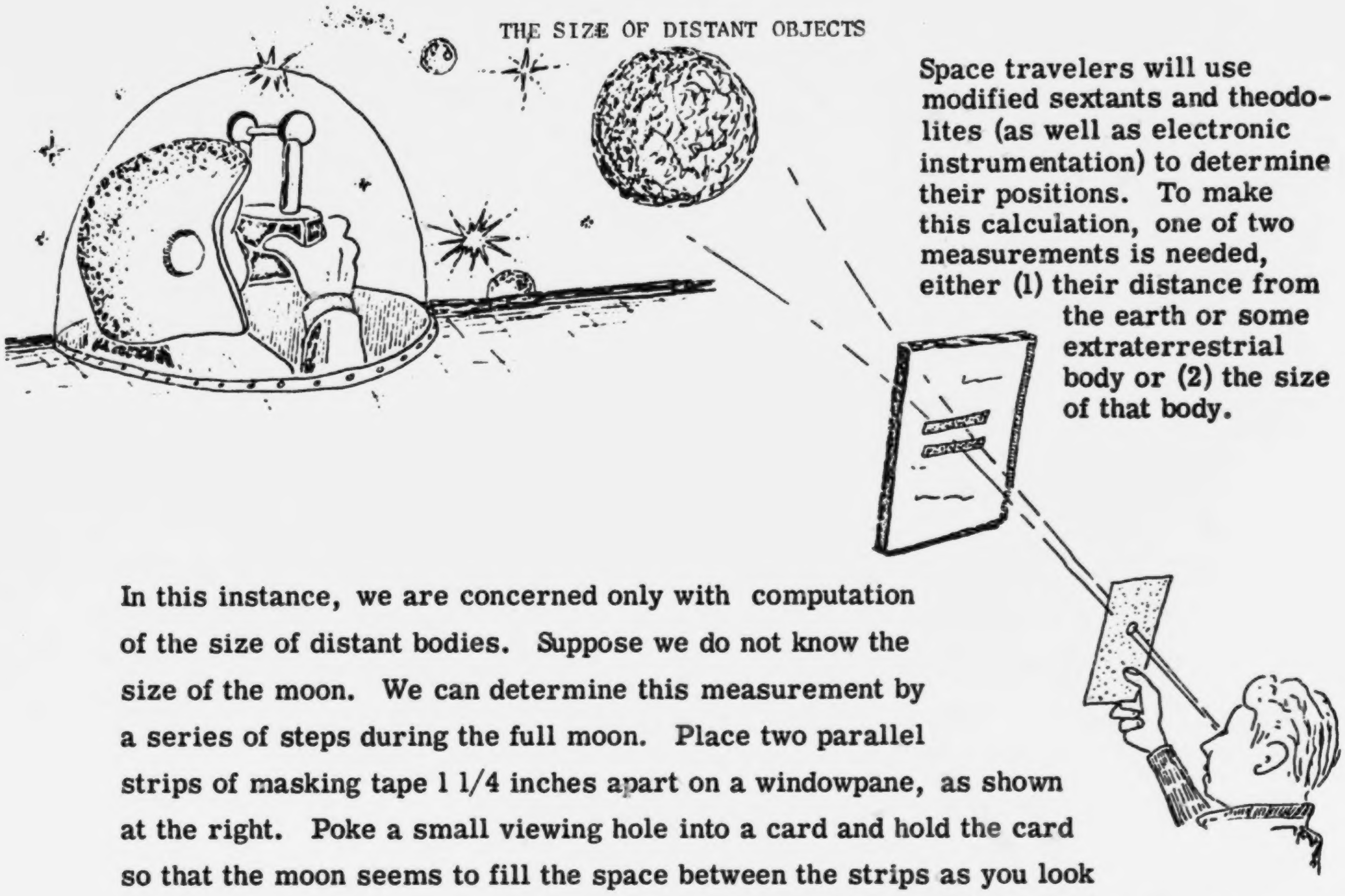
The principle behind these elaborate range finders can be illustrated with several pieces of wood and two pocketbook mirrors, arranged as shown in the illustration below, so that both mirrors are placed on the base at a 45-degree angle and parallel to each other. Both mirrors are fixed to small blocks. The mirror and block on the right are mounted on a movable arm. Inserted in the top of the block which backs the mirror to the left is a screw eye, or "viewing sight." Look through the viewing sight at some object and then shift the movable arm so that the right-hand mirror can reflect the object into the left-hand mirror. By measuring the difference between the original 45-degree angle and the angle now assumed by the right-hand mirror, a scale can be drawn to gauge the distance to the object. Note how the accuracy of the instrument is affected as the distance between the mirrors is changed.





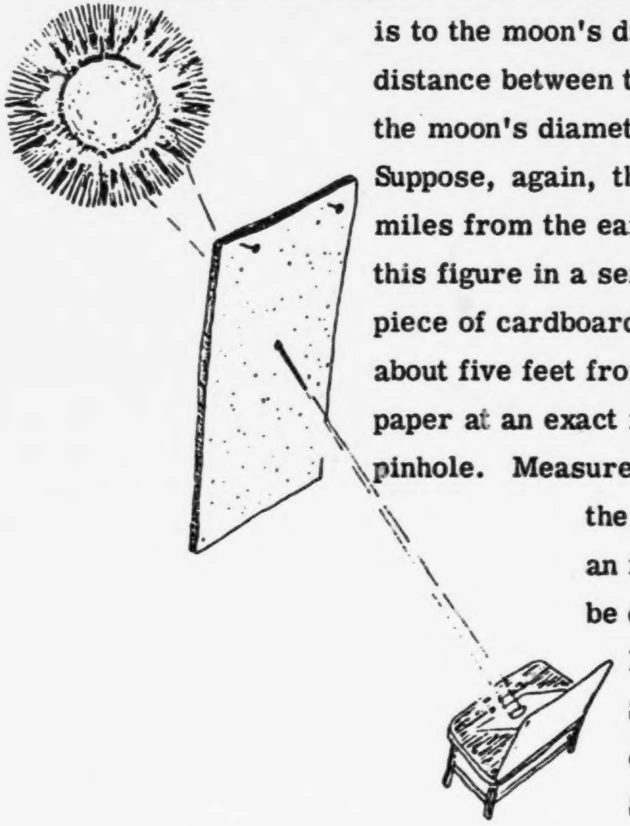
Reference: Adler, Irving. Seeing the Earth From Space. New York: Day, 1959.

THE SIZE OF DISTANT OBJECTS



Space travelers will use modified sextants and theodolites (as well as electronic instrumentation) to determine their positions. To make this calculation, one of two measurements is needed, either (1) their distance from the earth or some extraterrestrial body or (2) the size of that body.

In this instance, we are concerned only with computation of the size of distant bodies. Suppose we do not know the size of the moon. We can determine this measurement by a series of steps during the full moon. Place two parallel strips of masking tape 1 1/4 inches apart on a windowpane, as shown at the right. Poke a small viewing hole into a card and hold the card so that the moon seems to fill the space between the strips as you look through the "viewer." The distance from the card to the strips is in the same proportion to the distance from the earth to the moon as the space between the strips is to the moon's diameter. If 239,000 miles is accepted as the distance between the earth and the moon, a little figuring will show the moon's diameter within one percent of accuracy.



Suppose, again, that although we know the sun is about 93,000,000 miles from the earth, we do not know its size. We can arrive at this figure in a series of steps. Begin by making a pinhole in a large piece of cardboard and placing the cardboard, at either 9 am or 3 pm, about five feet from the floor and facing the sun. Place a sheet of paper at an exact right angle to the ray of light coming through the pinhole. Measure with a ruler the circle of light made by the ray on the paper, reading the measurement to sixteenths of an inch. The approximate diameter of the sun can then be determined by working out a simple proportion problem, like this:

Step 1 - Distance between pinhole to circle : size of circle :: distance between earth and : size of sun.

Step 2 - Size of circle X distance of sun = distance of circle from pinhole X size of sun.

Step 3 - $\frac{\text{Size of circle X distance of sun}}{\text{Distance circle is from pinhole}}$ = size of sun.

Reference: Johnson, Gaylord and Irving Adler. Discover the Stars. New York: Sentinel, 1957.

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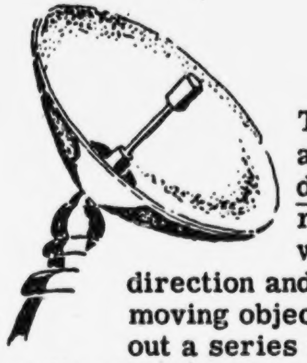
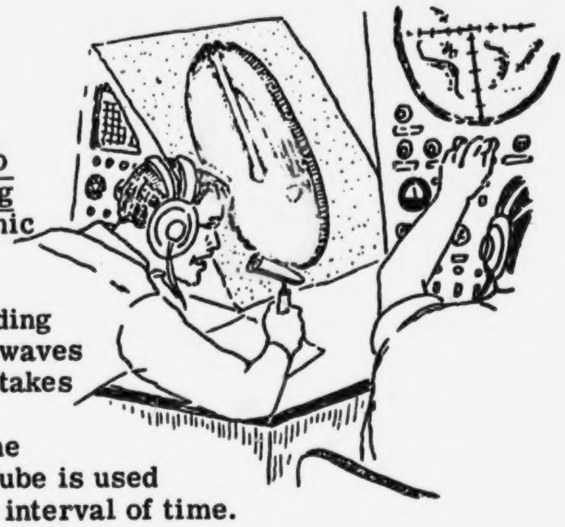


RADAR

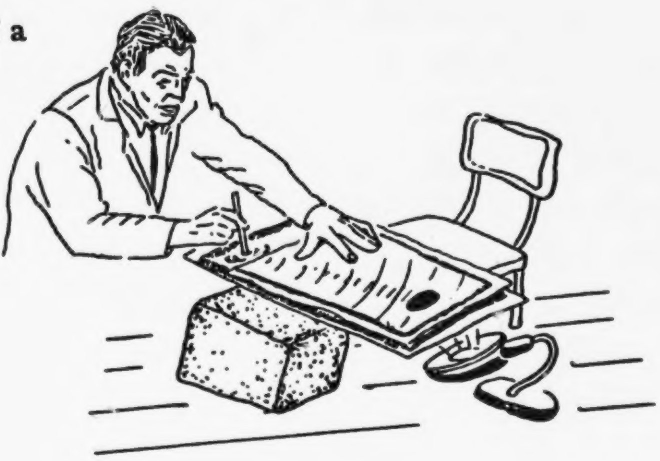


The word radar, an abbreviation of radio detection and ranging refers to an electronic way for finding the direction and the distance to a moving object. It works by sending out a series of electromagnetic waves (short radio pulses) and measuring the time it takes for the waves to bounce back from the moving object. Electromagnetic waves travel about one foot in a billionth of a second. A cathode ray tube is used for the most nearly exact recording of such an interval of time.

Radar in tracking stations located around the world fulfills the highly important function of determining the speed, altitude, and course— as well as possible deviation—of satellites and the separation stage and tumbling stages of rockets. Radar also gathers information about the surface characteristics of the moon and the atmospheric composition of other planets.

A ripple tank can aid in understanding how radar works. Build a ripple tank by attaching a one-inch wall of molding clay around the outside edge of a foot-square piece of window glass. Support the "tank" between two chairs, place a lighted lamp beneath it, and fill it with about a half-inch of water. Cut a small form out of wood or a tin can and place it at one end of the tank. Cover the entire tank with a piece of clean white paper but insert a pencil under the paper at one end of the tank and with it vibrate the water. Observe the shadows of the waves made by the pencil as they move toward and reflect from the test form.

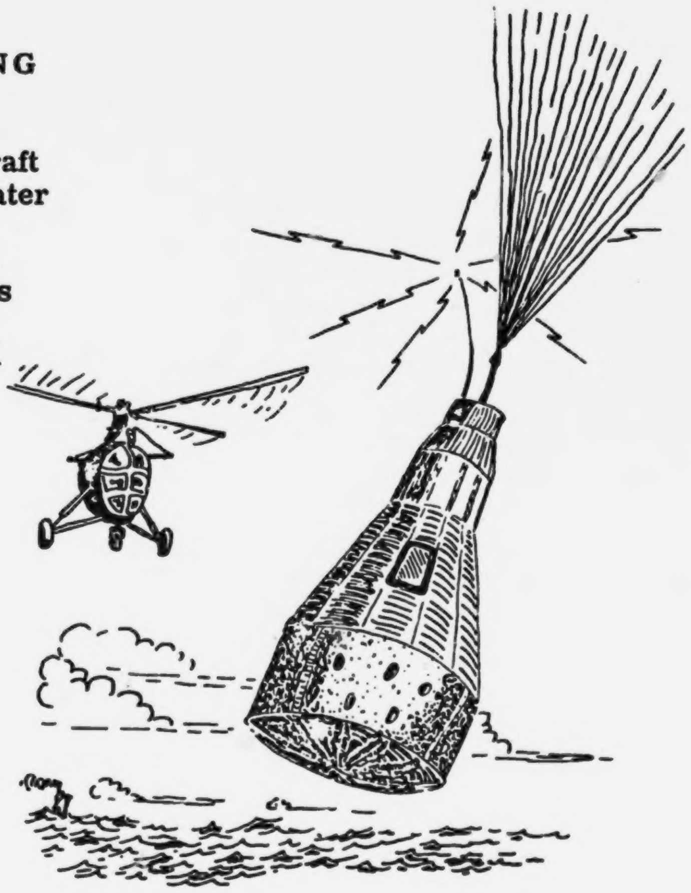
A small, soft, rubber ball tied to the end of a two-foot length of looped rubber bands will also help to understand the principle of radar. Close your eyes and grasp the end of the length of rubber bands. Toss the ball in all directions. With practice, the location and shape of objects in the room can be determined.



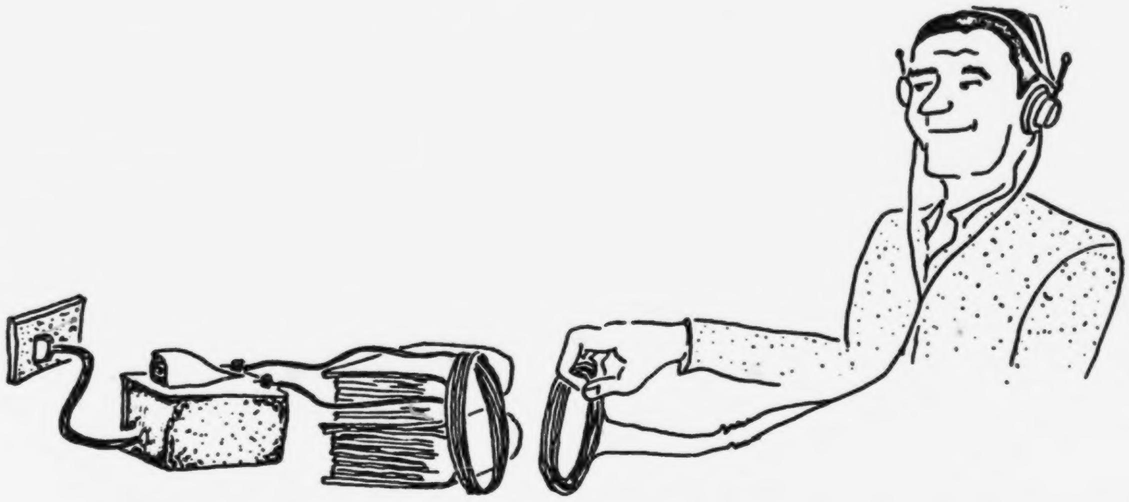
Reference: Kettering, Charles F. Short Stories of Science and Invention. Detroit: General Motors, 1959.

RADIO DIRECTION FINDING

After completing a mission, a spacecraft usually lands on some great body of water or in a sparsely populated area of the earth. So that its landing spot may be located as quickly as possible, it sends out a signal by radio beacon as it descends or after it lands. The signal is picked up by waiting aircraft or ground stations equipped with direction finders and a retrieval crew can immediately be on its way to the returned spacecraft.



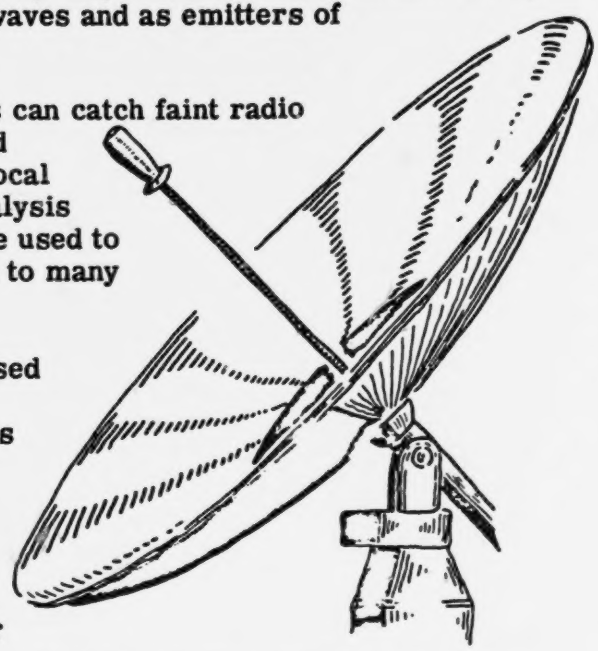
To experience the way radio signals find directions, connect a six-inch coil of many turns of fine, insulated electrical wire to the outlet terminals of a toy train transformer. Connect another, similar coil as a finder to a pair of earphones. Rotate the finder coil in the vicinity of the sending coil until the hum is loudest. The direction of the sending coil can thus be determined.



Reference: U. S. National Aeronautics and Space Administration, Manned Spacecraft Center. Results of the Second United States Manned Orbital Space Flight. Washington, D. C.: U. S. Government Printing Office, 1962.

SHAPED REFLECTORS

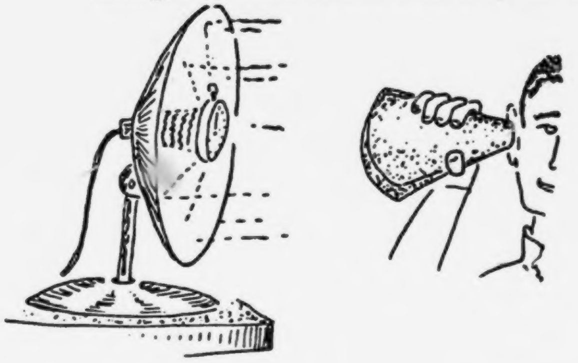
Shaped reflectors have been used for many years in headlights and searchlights. More recently, and especially in the last decade, they have been used in astronomy and astronautics as collectors of low energy waves and as emitters of parallel waves.



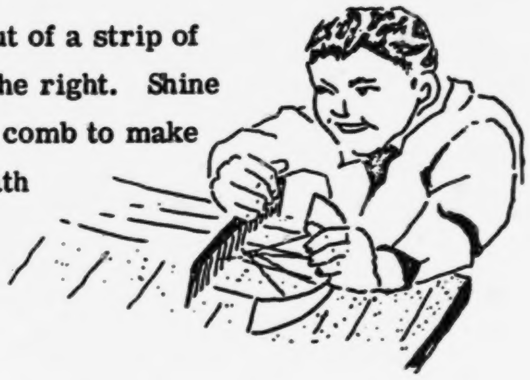
Reflectors shaped to collect low energy waves can catch faint radio disturbances from objects far out in space and send them forward, concentrating them at a focal point where they will be strong enough for analysis and study. Similarly shaped reflectors can be used to focus the sun's rays to bring temperatures up to many thousand degrees.

Reflectors shaped to emit parallel rays are used to throw energy in narrow lanes to a distant object, so that the energy will bounce back, as in radar.

To see how a shaped reflector can collect and redirect sound waves, suspend a clock over the center of an electric heater reflector and put a cardboard cone to your ear, as shown in the illustration at the left. You will be able to hear the ticks of the clock many feet away. Try moving the clock around inside the reflector. Notice where the sound is the loudest.

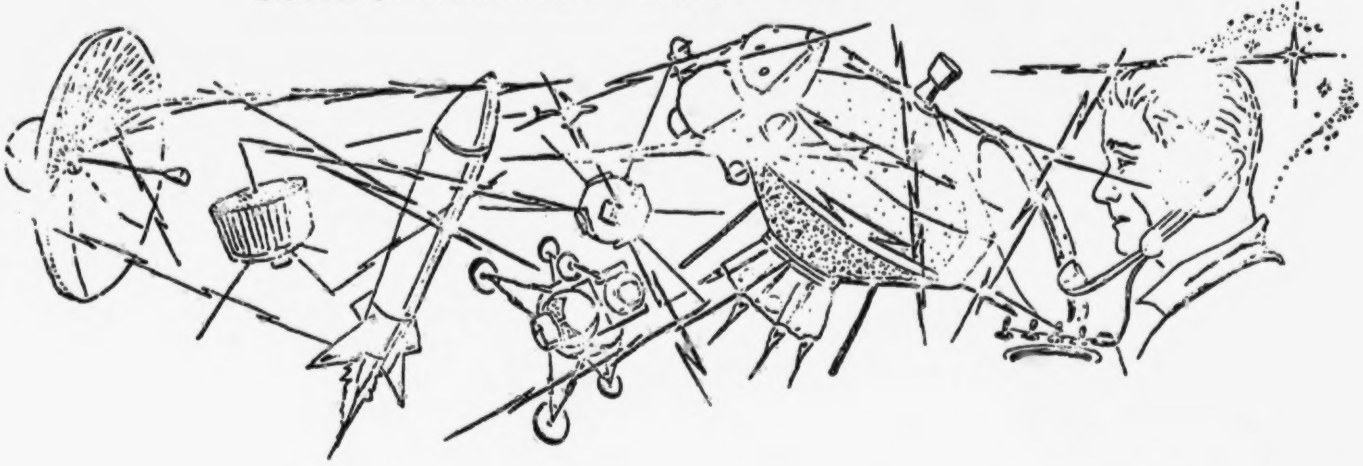


Make a flexible reflective surface out of a strip of metal from a tin can, as shown at the right. Shine the light from a projector through a comb to make parallel rays of light. Notice the path taken by these light rays as the reflector is moved and bent in various ways.



Reference: Smith, F. Graham. Radio Astronomy. Baltimore: Penguin, 1960.

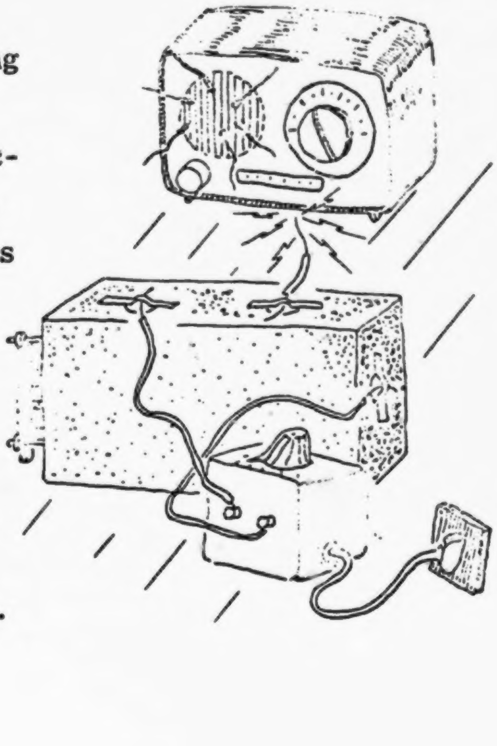
COMMUNICATIONS EQUIPMENT



The communications equipment on board a spacecraft consists of three basic parts: transmitter, antenna, and receiver. The transmitter converts electrical power into r.f. (radio frequency) impulses or waves. These waves are fed into an antenna and, depending on the form of the antenna, are radiated in many directions, going out through air and space in straight lines. They travel at the speed of light, i.e., 186,000 miles per second. When r.f. waves strike a second, receiving antenna, they generate tiny electrical currents which can be amplified by a receiver into strong signals. (R.f. waves are also known as hertzian waves, for Heinrich Hertz, the German physicist.)

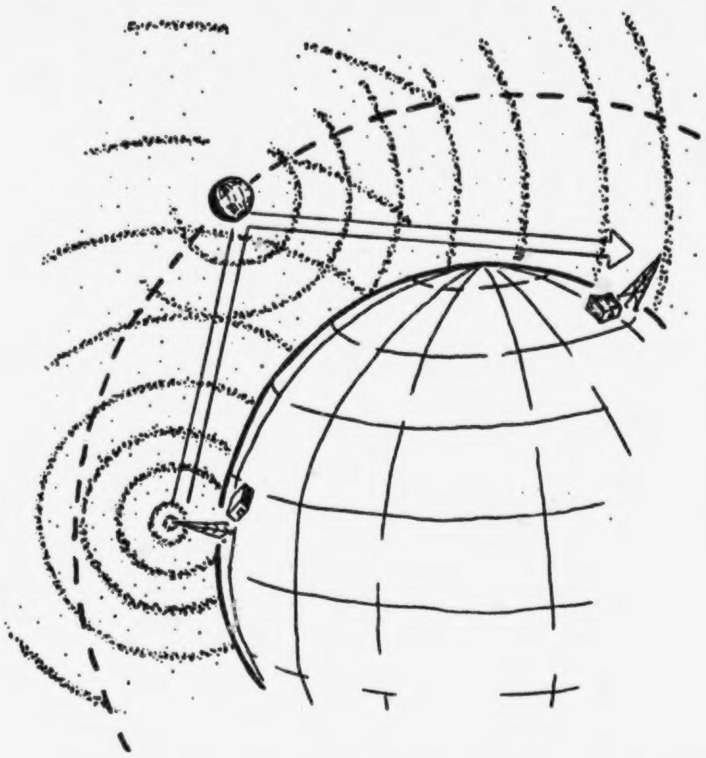
When a transmitter is turned rapidly on and off with a telegraph key or an automatic instrument-reading device, a coded message can be heard at a receiver. By adjusting the incoming message through a microphone, the sound waves generated by the receiver duplicate the voice waves of a transmitting operator.

Send a radio signal from one part of a building to another by using an ignition spark coil (designed for Model T Fords or Fordson tractors and obtained from any large auto supply store) as the generator of the r.f. waves. As the electromagnetic disturbances strike the antenna of any common AM (amplitude modulation) radio, the signal can be "read."



CAUTION - Do not connect the spark coil to an antenna system. The radiations may disturb licensed communications controlled by the Federal Communications Commission.

Reference: Lewellen, John. Understanding Electronics - From Vacuum Tube to Thinking Machine. New York: Crowell, 1957.

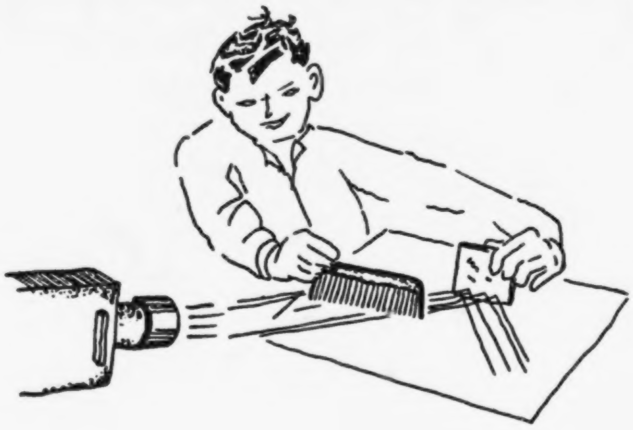


COMMUNICATION SATELLITES

High frequency radio waves, of which television is a good example, tend to travel out from transmitting stations in straight lines. This characteristic has presented difficult problems in attempts at world-wide communication via H. F. To cover large areas effectively, H. F. must be transmitted from a very high point, such as a tall tower atop a mountain. To pass from one area to another around the curvature of the earth, H. F. once required a complicated cable system of relay towers about every 200 miles.

Today, through the efforts of communications scientists, a far simpler and more efficient method is used. High frequency radio waves can now be transmitted across much of the earth's surface by using a reflector, a simple, mirror-type device or a small relay transmitter high above the earth. The passive satellites in the Echo program, as well as the active communication satellites, Telstar, Relay, and Syncom, have all proven their effectiveness.

To visualize the way in which high frequency radio waves can be transmitted great distances, hold a comb so that the rays from the sun or from a bright light (for example, the light from a 35 mm projector) shine through the comb's teeth and fall on a sheet of paper lying flat. Place a mirror diagonally in the path of the beam of light. Notice how they are reflected and how the angles change as the mirror is moved.



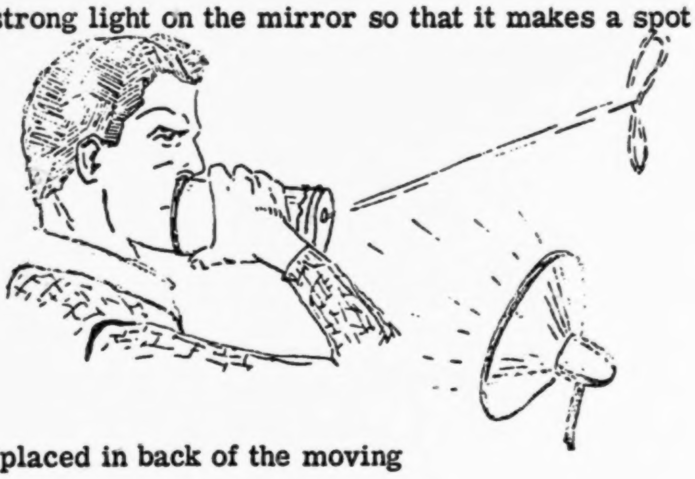
Reference: American Telephone and Telegraph Co. Countdown to Tomorrow.

EXTRATERRESTRIAL COMMUNICATION

About one-fourth of one percent of the 100 billion known stars in our galaxy may possess planetary systems capable of supporting life similar to that on earth. Theoretically, life on some of these planets could have begun a billion years earlier than ours and, if so, have attained a highly advanced state of civilization by now. Should this theory be borne out, it will probably also be true that the physical structure of inhabitants of the planets will be widely different from ours, as will be their sensitivity to common, earth-type phenomena such as light, sound, heat, and all other electromagnetic forces. Accordingly, many scientists believe, it may be extremely difficult to communicate with these natives of other worlds.

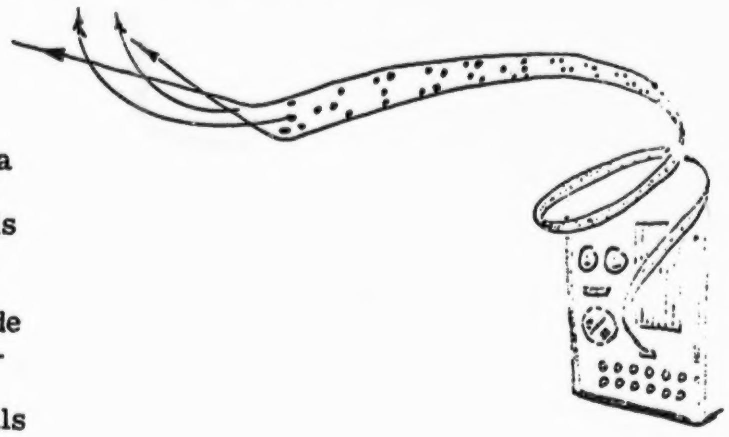
Space anthropologists, however, are formulating a means of communication with other living beings who may still be at our own cultural level. To surmount their possible inability to react to the same type of electromagnetic waves to which humans respond, ideas are being transformed into a continuous wave pattern. This formulation is in keeping with the continuously variable pattern of most natural physical phenomena, such as, for example, the rhythmical movement of air molecules, the pressure in circulatory systems, and the flow of electric current through wires.

To transform sound vibrations into a continuous flow pattern of light, cut both ends out of a small tin can and stretch part of a rubber balloon over one end, fastening it with an elastic band. Glue a small piece of mirror on the balloon, half way between the edge and the center. Shine a strong light on the mirror so that it makes a spot on the wall or ceiling. Press the open end of the can against your mouth and say words with varying sounds. Notice how the spot of light on the wall or ceiling vibrates, making different patterns for different sounds or words. If a moving, photographic recording tape were placed in back of the moving spot, it would record the sounds as a continuous fluctuating line.

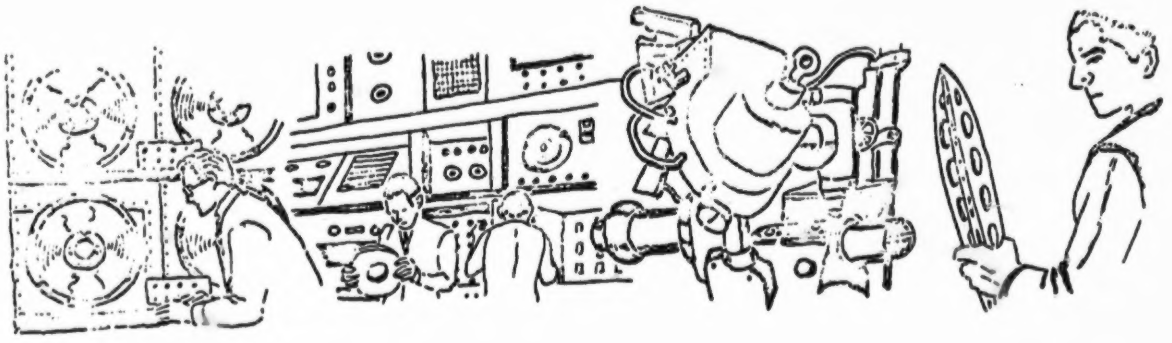


Reference: Guilbaud, G. T. What Is Cybernetics? New York: Grove, 1960.

TALKING MACHINES - THE COMPUTER

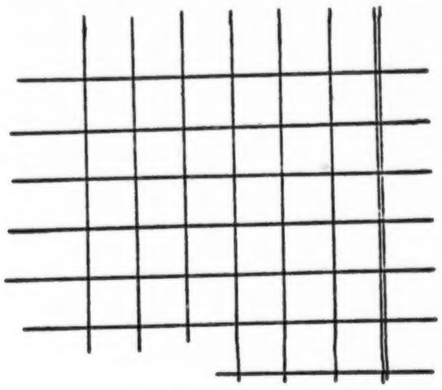


Space age scientists have developed a new kind of electronic "brain." Not only does it understand the commands of humans but it translates human ideas into detailed instructions for machines. It is used not only to guide machines in making complex production processes but also to develop new and unique products and materials in the field of experimental design.



In this type of automatic programming, each letter in the instructions is represented by a binary number. A binary number is made up of a combination of only two digits: zeros and ones. The last number in a code series indicates the number of units (ones). The next digit to the left indicates the number of twos; the next digit, the number of fours; the next, eights; then, sixteens; and so on, doubling each time.

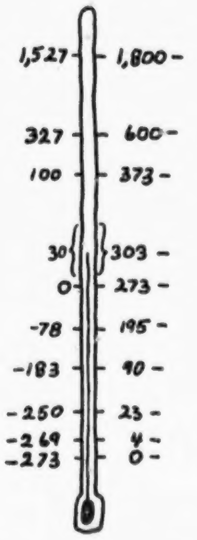
11010 16
8
0
2
+0
26 or letter Z



A = 1; B = 10; C = 11; D = 100; E = 101, etc. M, the 13th letter of the alphabet, would be 1101 and recorded on the punch tape as

Reference: Esso Standard Oil Co. Yes, No - One Zero. New York: Esso Standard Oil Co., 19

CRYOGENICS



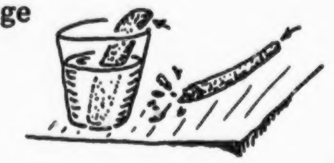
The science which deals with the changes in common properties resulting from extremely low temperatures is called cryogenics. According to cryogenics, as temperatures approach absolute zero on the Kelvin scale (i. e., -275 degrees Centigrade), molecular movement slows down; when temperatures reach absolute zero, all molecular movement theoretically stops. The Kelvin scale is used by cryogenic engineers to avoid having to express negative temperature readings.

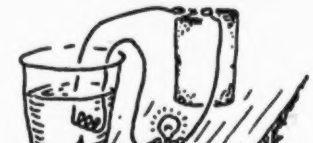
Many laboratories are testing the effect of very low temperatures on materials and finished components of future spacecraft. One of the most promising uses of low temperature science is the production of rocket fuels which can be stored in outer space. Liquid hydrogen and oxygen are good examples of cryogenic fuels.

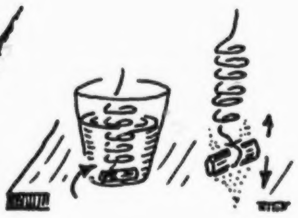
A mixture of dry ice and acetone can produce a temperature of about -80 degrees Centigrade, the lowest near-cryogenic temperature which can be easily produced. Cover a few pieces of dry ice with a piece of cloth and break them into small pieces by hitting them with a hammer. Drop the ice, a small amount at a time, into six ounces of acetone contained in a quart thermos bottle. After the bubbling subsides, add more dry ice to make a mushy mixture. Notice the change in character of various substances when exposed to this very low temperature.

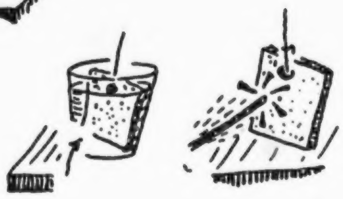
CAUTION

Wear thick gloves when handling dry ice or anything frozen with it! Never confine dry ice or the frozen mixture in a closed container.



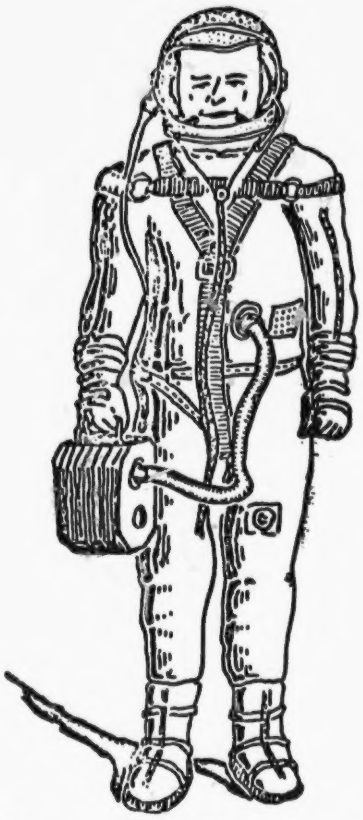






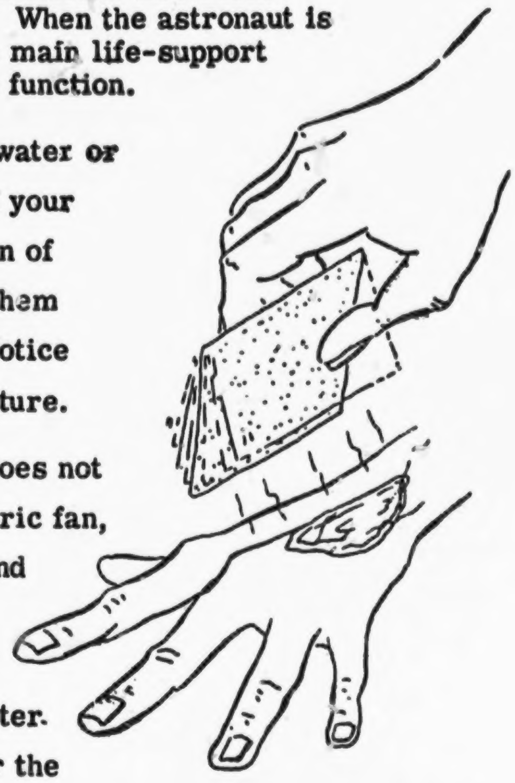
Reference: Loveman, William H. The Story of Oxygen. Cleveland: Burdett Oxygen Co.

SPACE SUIT AIR CONDITIONING

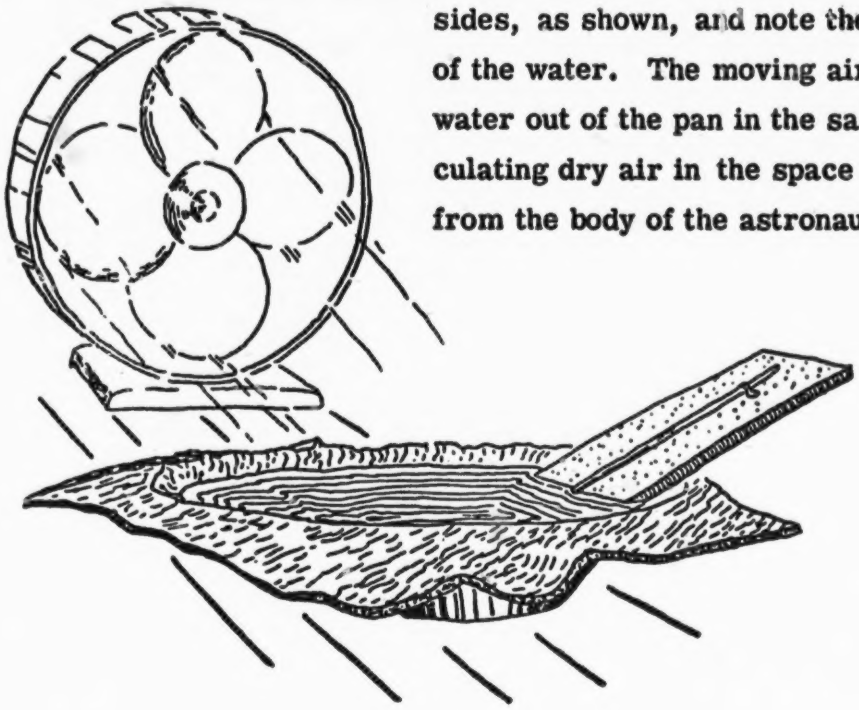


In moving from the conditioning room, where they are dressed, "wired," and briefed, to the spacecraft, astronauts use portable air conditioning units to keep their airtight pressure suits from becoming uncomfortable. Circulating dry air throughout the inside of the suit removes the moisture and cools the astronaut's body. When the astronaut is in the spacecraft, the main life-support system performs this function.

Place a few drops of water or alcohol on the back of your hand. Aid evaporation of the drops by fanning them with a small card. Notice the change in temperature.

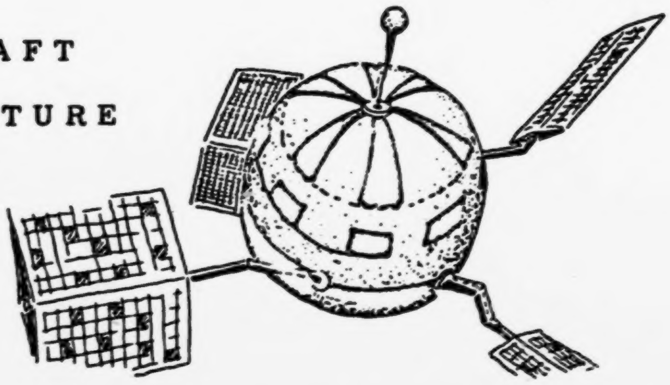


Why moving air in the astronaut's suit cools him but does not cool the suit or the capsule can be shown with an electric fan, a pie plate of room-temperature water, a washcloth and a thermometer. Hold the thermometer in the breeze of the fan and note the reading. Place it in the water and let the fan blow on the water. Read the thermometer again. Place the washcloth in the pan, draping it over the sides, as shown, and note the change in temperature of the water. The moving air helps to evaporate the water out of the pan in the same way that the circulating dry air in the space suit removes perspiration from the body of the astronaut.



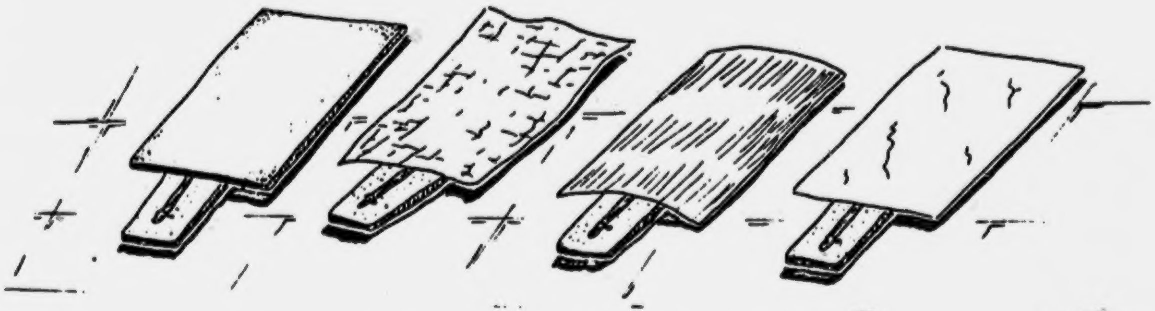
Reference: Gaul, Albro. The Complete Book of Space Travel. New York: World, 1956.

SPACECRAFT TEMPERATURE CONTROL

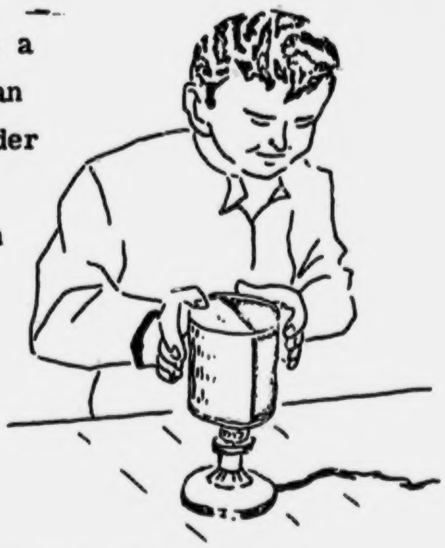


The internal temperature of many spacecraft is partially controlled by using different types of construction materials and painting them in patterns of black and white or of colors. Thus, the absorption and radiation of heat by the craft can be balanced to some extent and the on-board equipment can operate in temperatures that approximate those within the earth's range.

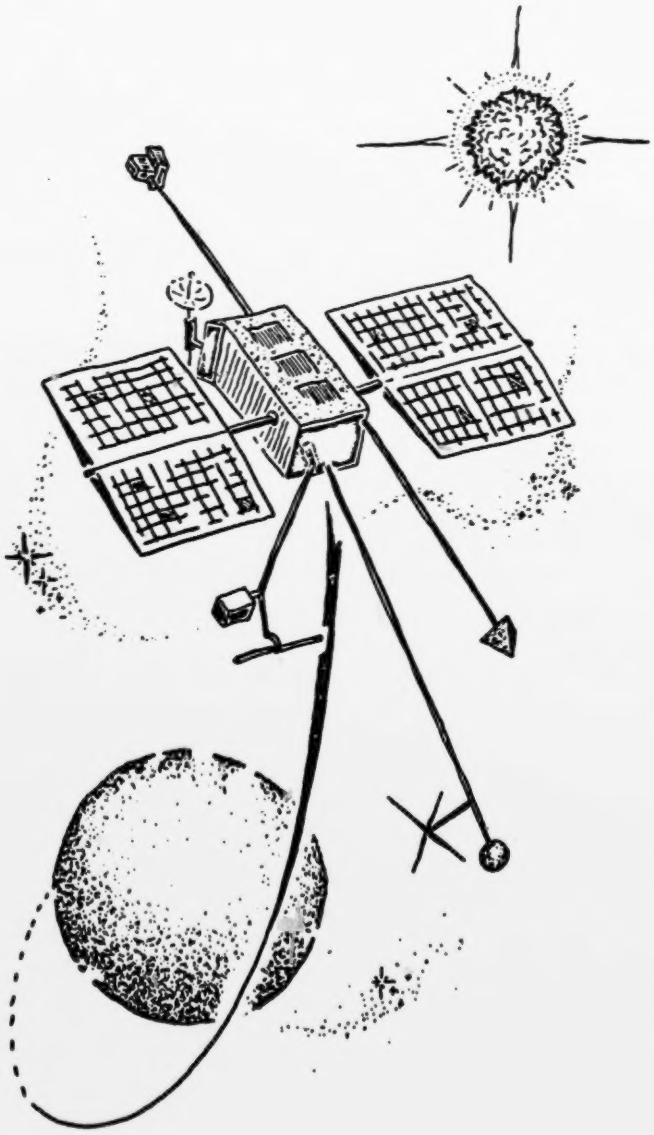
To experience the way some materials and colors absorb more heat than others, place thermometers under different materials and different colors of the same material and note the differences in temperature of the test materials when they are exposed to sunlight for a period of time.



Also, paint half of a large tin can, inside and outside, a flat black and leave the other half shiny. Place the can over a lighted bulb of a lamp, using a lamp shade holder or a piece of bent wire to hold the can away from the bulb. Feel the difference in the heat radiated through each half of the can.



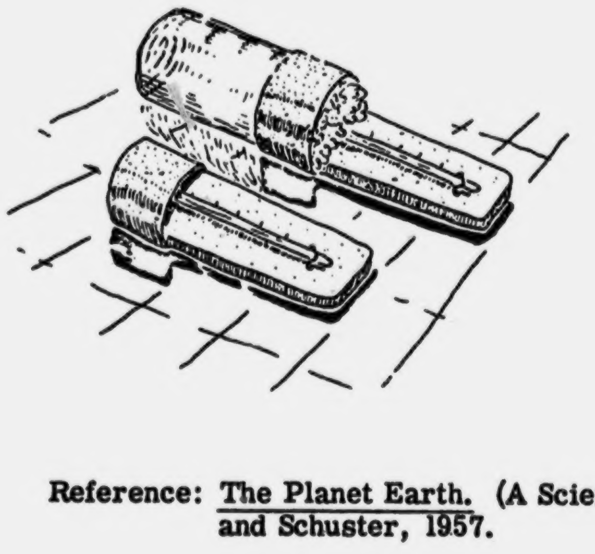
Reference: Foster, Ronald M., editor. Satellite Communications Physics. Bell Telephone Laboratories, 1963.



HEAT TRAP

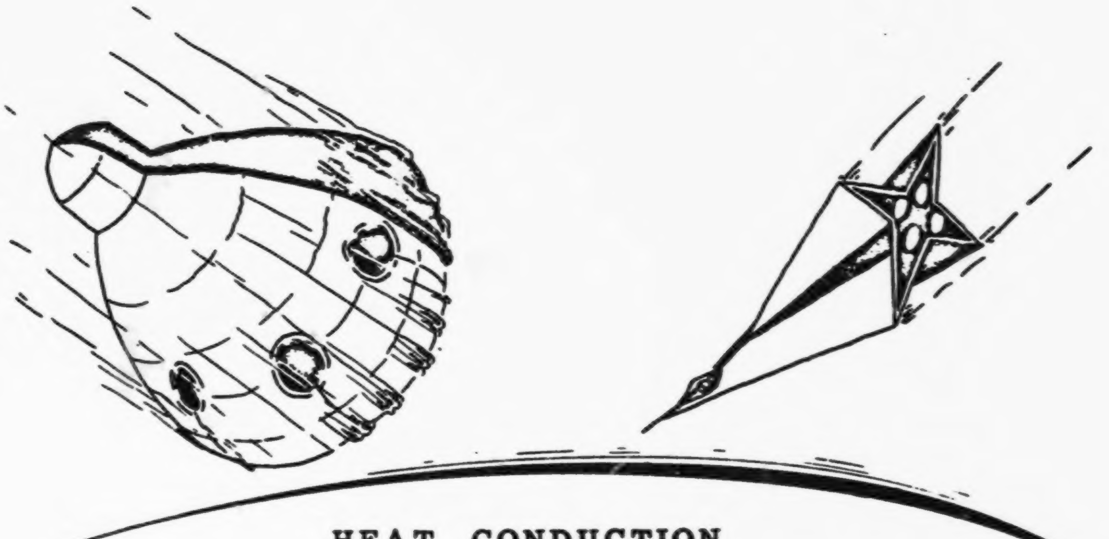
Scientific research has long been concerned with the balance between heat loss and gain in different parts of the earth and its effect on surface conditions. This research begins with the basic fact that the earth's atmosphere traps solar warmth. Short energy waves radiated from high temperature sources, such as the sun and electric lights, can readily pass through the atmosphere, but longer waves, radiated from radiators, warm soil, and other sources of comparatively low temperature, pass through with difficulty. This characteristic of the earth's atmosphere is known as the Greenhouse Effect.

One-way passage of heat is also a characteristic of glass. Greenhouses and other buildings with large expanses of glass illustrate that short energy waves of sunlight pass through glass with ease but comparatively longer, low-temperature waves from the warmed air cannot escape.

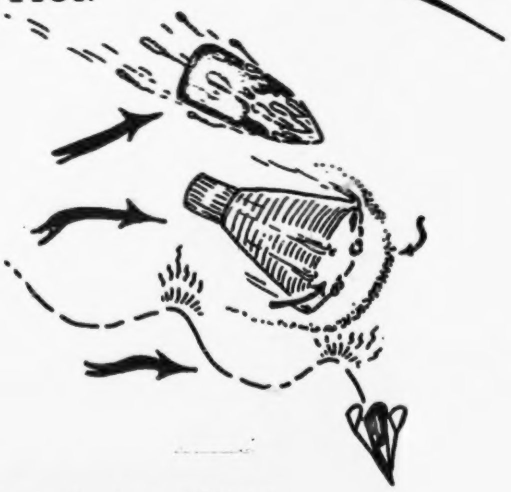


With cotton, seal a thermometer in a jar and protect it from direct light by a band of paper around the jar. Use a similar thermometer, protected from direct light with another band of paper, but do not put the second thermometer in a jar. Place both thermometers in the sunlight or the light from an electric bulb. After a few minutes, compare the two.

Reference: The Planet Earth. (A Scientific American Book) New York: Simon and Schuster, 1957.

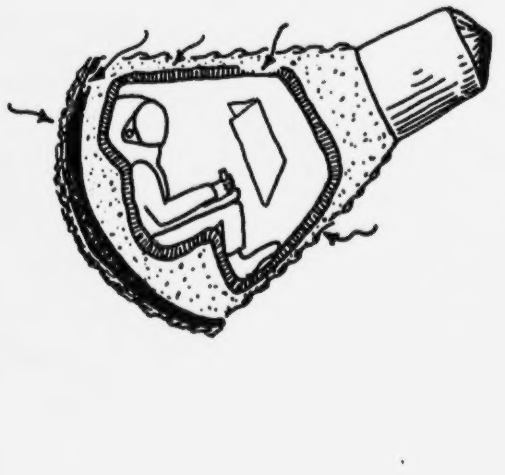


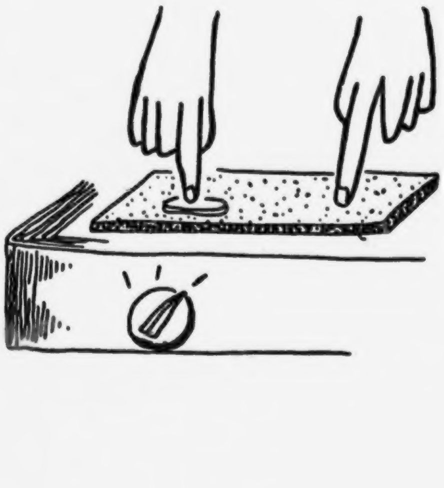
HEAT CONDUCTION



Re-entry vehicles must be built so that the frictional heat created by the atmosphere will not affect the function of the spacecraft. Various ways to answer this problem have been developed, including designing some vehicles shaped to "push" the greatest heat ahead of itself into the air and others constructed to use aerodynamic lift so that the heat is given off back into space. Still a third, and important, method is the use of materials designed to resist very high temperatures.

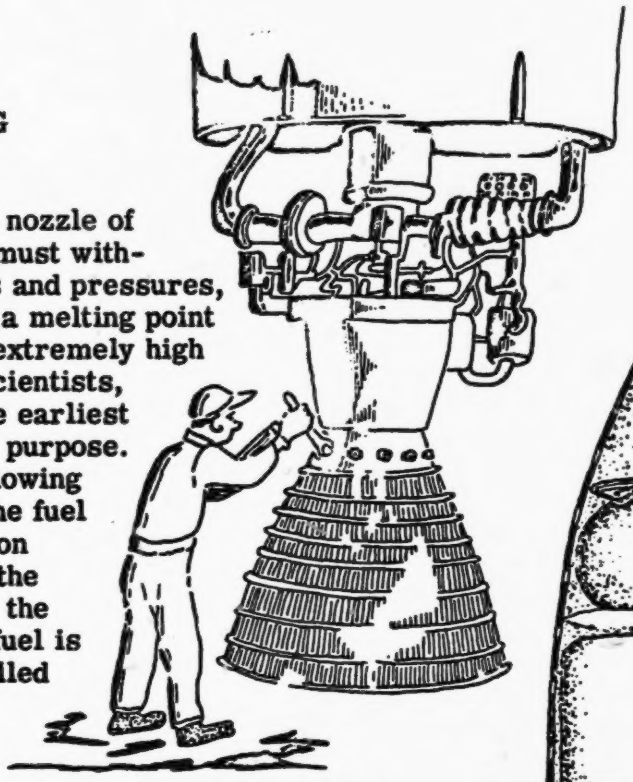
To test out the fact that some materials are good conductors of heat while others are heat resisters, place an asbestos mat over a low heat and lay a penny on it. Periodically touch the penny with one finger and the mat with another. You will soon find the penny too hot to touch, although you can still touch the mat. A thermometer will indicate the relative temperature of both materials.



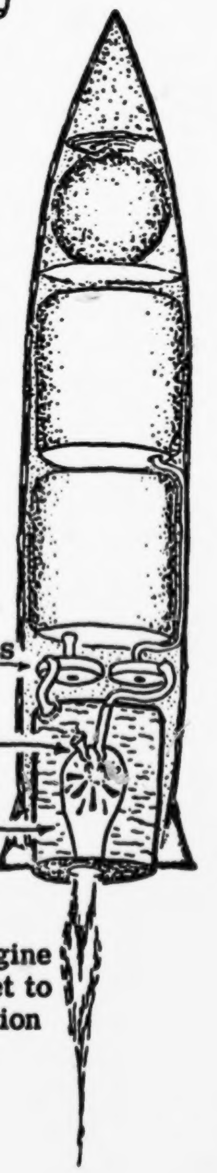


ENGINE COOLING

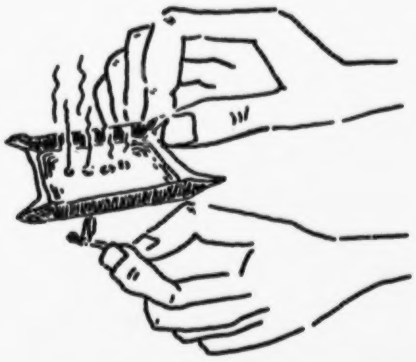
The combustion chamber and nozzle of liquid-fueled rocket engines must withstand very high temperatures and pressures, but there is no material with a melting point high enough to tolerate such extremely high temperatures. The rocket scientists, therefore, still use one of the earliest techniques developed for this purpose. This technique consists of allowing cool fuel to flow down from the fuel tank and around the combustion chamber before it flows into the combustion chamber. Thus, the chamber is cooled while the fuel is warmed. This process is called regenerative cooling.



To experience the way regenerative cooling works, fold the corners of an ordinary file card so that it will hold a small amount of water. Hold this improvised boiler over a lighted match or other heat. Notice that the water will boil but the card will not catch fire because the water conducts the heat away from the paper so quickly that the paper does not get hot enough to burn.

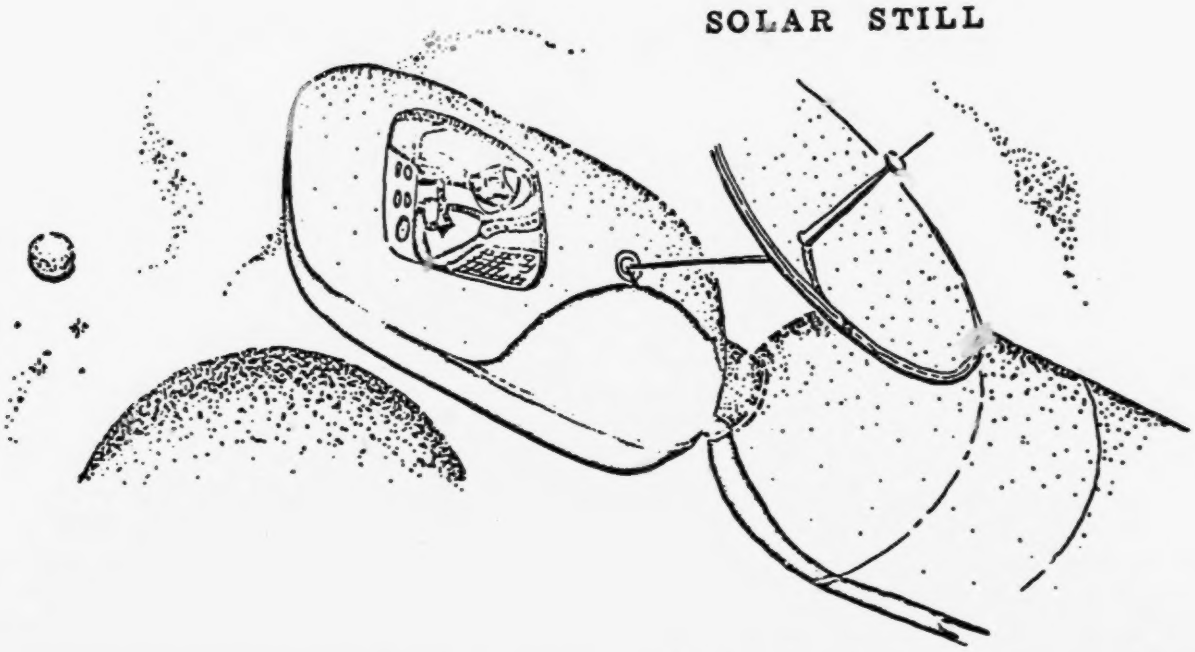

Pumps
Fuel enters combustion chamber
Cold fuel around outside of combustion chamber

Simple rocket engine using a fuel jacket to keep the combustion chamber cool.



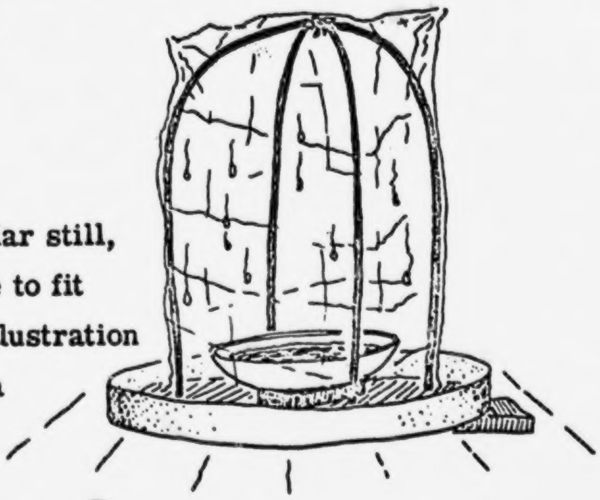
Reference: Corless, William R. Propulsion System for Space Flight. New York: McGraw, Hill, 1960.

SOLAR STILL

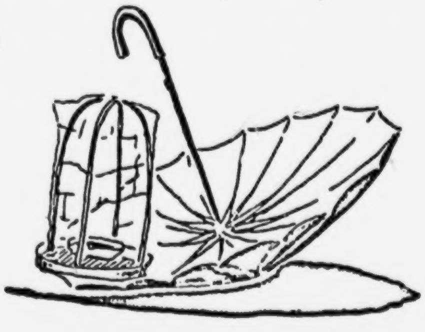


As populations expand across the earth, mankind is faced with a major problem: how to attain more pure water. Natural sources of fresh water will prove increasingly inadequate in the future. Scientists today, therefore, are turning to the ocean as a possible source of supply and to the sun's energy as a means to purify ocean water.

A limited water supply is also a problem on manned spacecraft. Distillation of waste water, however, purifies it so that it can be used over and over again. In this way a small amount can last a long time.

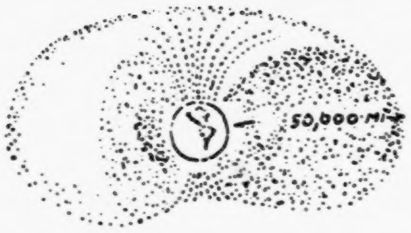


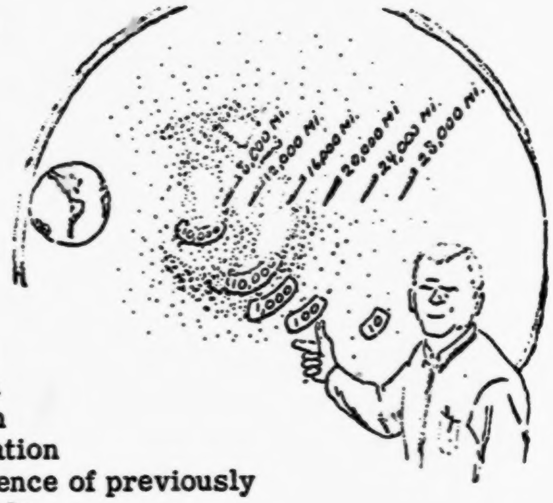
A simple distillation apparatus, called a solar still, can be made by bending a coat hanger frame to fit into a small plastic bag. As shown in the illustration at the right, stand the hanger in its bag on a large tray and over a small bowl holding undistilled liquid. Move the entire apparatus into the sunshine and notice the distillation process. Place an umbrella, painted silver on its inner side, under the distillation unit. Face the umbrella toward the sun and note any changes in the rate of the process.



Reference: Branley, Franklyn M. Solar Energy. New York: Crowell, 1957.

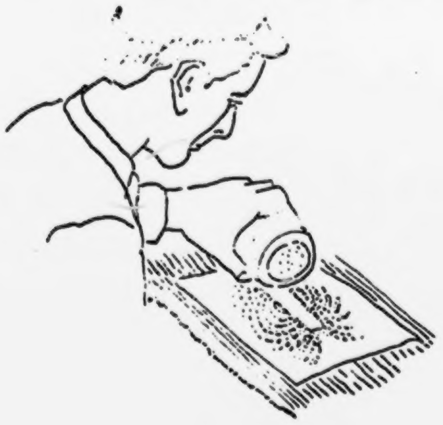
THE MAGNETOSPHERE





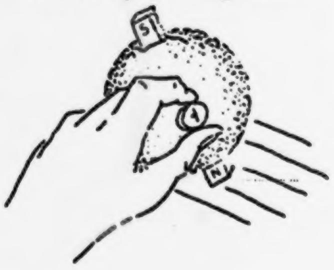
The first American satellite, Explorer I, launched in January, 1958, loosed a deluge of brand new data concerning the regions surrounding the earth. With succeeding space probes, the scientific instrumentation carried by the rockets and satellites delivered evidence of previously unknown phenomena for continuing research and study.

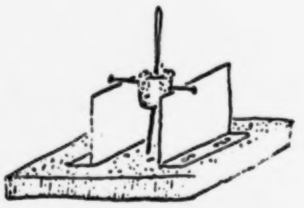
The Explorer and Pioneer probes established that the earth is surrounded by an area, known as the magnetosphere, of energetic particles controlled by the earth's magnetic field. As far as we know today, this area, named the Van Allen belt in honor of physicist James A. Van Allen, begins at about 400 miles above the earth's surface. With varying degrees of density, it extends for thousands of miles into space. The size and shape of the magnetosphere seems to depend upon the high energy, sub-atomic particles (electrons and protons), plasma clouds, and other radiations emitted from the sun at the time of major solar flares and upon the earth's magnetic field.



The cause of the earth's magnetism is a mystery. A miniature magnetic field with a similar pattern of operation, however, can be created by placing a bar magnet under a piece of paper and sprinkling iron filings on the top of the paper.

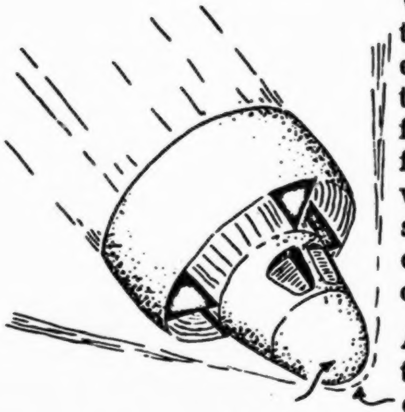
Make a model of the earth's magnetic field by pushing a bar magnet through a hole tunneled in a rubber ball. Explore the magnetic field surrounding the ball with a small compass. Check the angle at which the earth's magnetic-field lines strike the earth by using a dip needle (i.e., a magnetic needle which will 'dip' from the horizontal when suspended free to swing in a vertical plane). To do this, push a large, non-magnetized needle through a small cork and balance it by sticking two straight pins in the side so that the needle rests in a horizontal position. Now magnetize the needle by rubbing it in one direction with a magnet, and place it on a cardboard support as shown at the right. Note that the geographic latitude can be determined quite accurately by this means by measuring the angle of the needle with a protractor.





Reference: Burgess, Eric. Frontier to Space. New York:
Crowell-Collier, 1962.

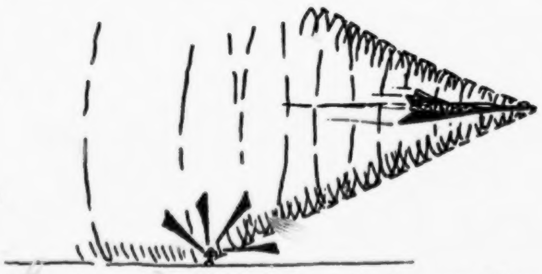
SHOCK WAVES



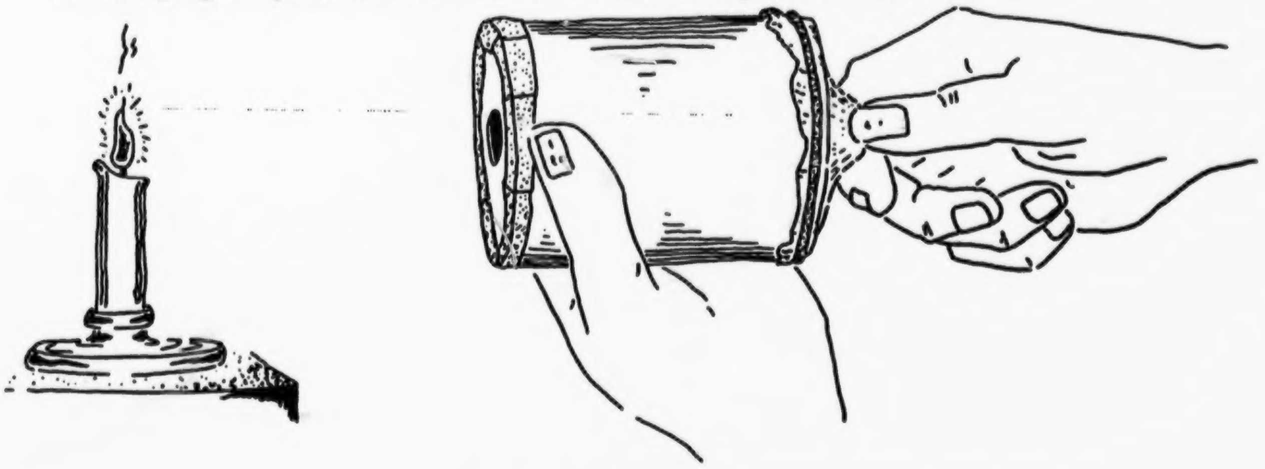
When a spacecraft slashes back into the earth's atmosphere, the force and speed of its re-entry create shock waves. The effect is an immediate build-up of frictional heat of such intensity that the capsule might disintegrate were it not for one factor. That factor is the design of the spacecraft, whose forward area is shaped specifically to deflect the shock waves. Thus deflected, or bent around the spacecraft, the shock waves—searing hot in themselves—form a protective cushion between the vehicle and the even higher temperatures of the surrounding atmosphere.

Another kind of shock wave, but in this case more like a wall than a wave, is created when the speed of trans-sonic aircraft and rockets approaches the speed of sound, i.e., 760 miles per hour at sea level. A vehicle traveling at this speed piles up molecules of air in front of it until they form a wall of high pressure. By increasing its speed, the vehicle can penetrate this wall. In so doing, however, it will be buffeted as if in a violent storm.

Aircraft and rockets which travel faster than the speed of sound drag a compressed air barrier behind them similar to the wake that follows a speed boat. As the wake of the boat slaps against other objects in the water and against the shore, just so does the compressed air barrier trailing a supersonic craft hit the ground with the familiar boom often heard as such a vehicle travels through the nearby skies.

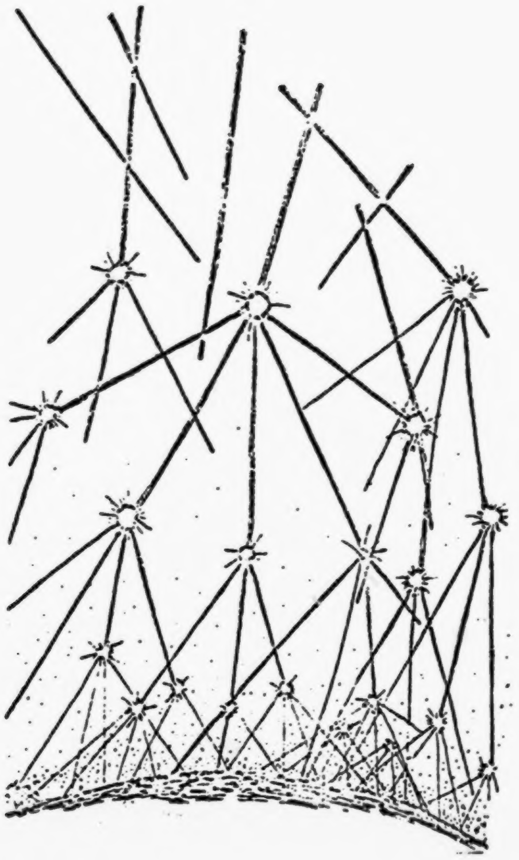


To experience the effect of a compressed air barrier, cut the ends out of a medium-sized tin can. Cut a half-inch hole in the center of a round piece of light cardboard (a file card cut to fit will do) and tape this over one end of the can. Stretch a piece of balloon rubber across the other end and secure with an elastic band. Pluck the balloon rubber and feel the shock wave come from the opening in the cardboard end. Light a candle and, placing it a few feet away, point the cardboard end of the can toward the flame. Again pluck the balloon rubber and notice the action on the candle flame. Have someone blow smoke into the can. This time, as the balloon rubber is plucked, watch the changing shape of the smoke wave as it emerges from the can.



Reference: Sutton, O. G. The Science of Flight. Baltimore: Penguin Books, Inc., 1955.

SPACE RADIATION - COSMIC RAYS -



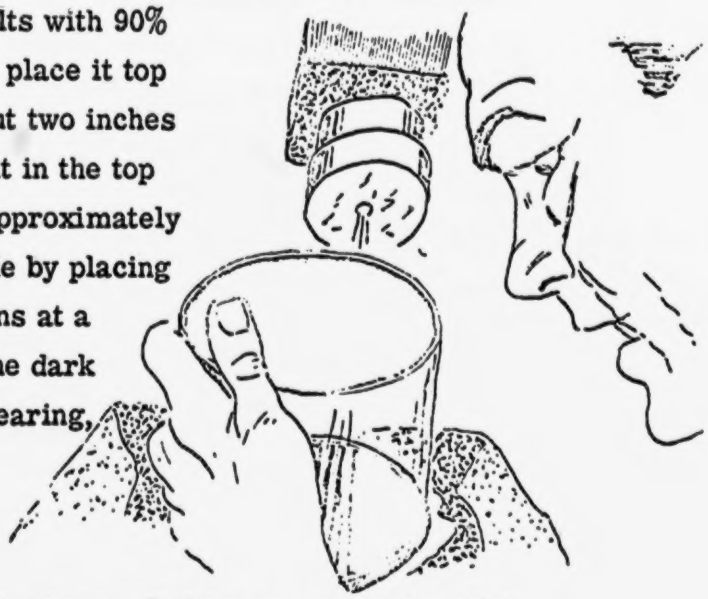
The primary source of space radiation is cosmic rays. These radiations from deep space are powerful enough to penetrate 18 inches of solid lead or 200 feet of water. Space travelers on long journeys will have to be protected from the damage these rays can do to human tissue and when they land on such places as the moon or Mars shelters with thick roofs will have to be constructed to shelter them.

Secondary cosmic rays pass through our bodies at the rate of about 1,500,000 a day, but we do not experience radiation damage because the rays have been depleted of all but a small amount of energy. On entering the earth's atmosphere, the primary cosmic ray collided, at an altitude of about 25 miles, with molecules of air. The air molecules were shattered and the energy of the cosmic ray distributed among the particles. These, in turn, collided with other molecules and the process continued until the cosmic particles reached the surface of the earth. Each particle then possessed less than a millionth of the energy of the primary ray.

A Wilson cloud chamber offers one method for observing cosmic rays. It is based on the fact that supersaturated vapor will condense more readily on ions than on neutral molecules. When a secondary cosmic ray passes through the air, it breaks off parts of molecules, leaving electrically charged atoms or ions.

The ions left behind by the passage of a cosmic ray readily gather tiny droplets of water in the saturated vapor of the cloud chamber. These can be seen reflected in a beam of light.

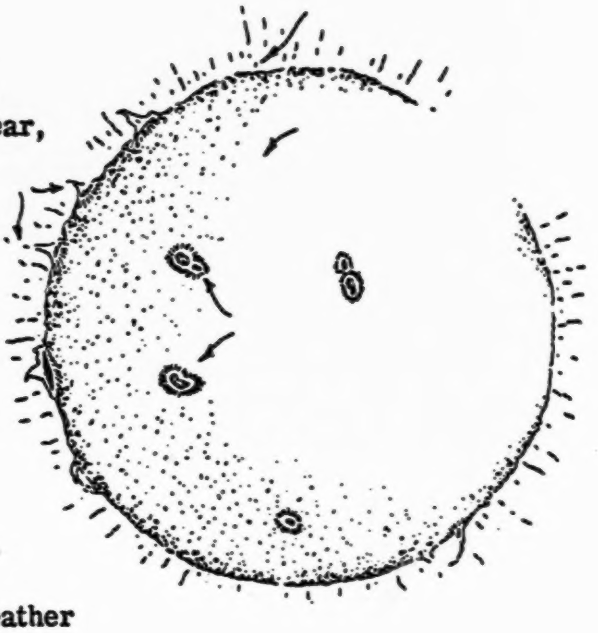
A model cloud chamber can be made by following these steps: Place carefully fitted circles of black felt against the bottom and top of a small screw-cap jar (about 4 x 4 inches). Fully saturate the felts with 90% methyl or ethyl alcohol, close the jar, and place it top down on a five-pound piece of dry ice, about two inches thick, wrapped in newspaper with a hole cut in the top wrapping to accommodate the jar. After approximately 15 minutes, adjust a fine beam of light made by placing an aluminum foil cover over a projector lens at a sloping angle. Look through the beam at the dark background and notice the cloud tracks appearing, one at a time, at uneven intervals.



Reference: Smith, F. Graham. Radio Astronomy. Baltimore: Penguin, 1960.

CHROMOSPHERIC ERUPTIONS

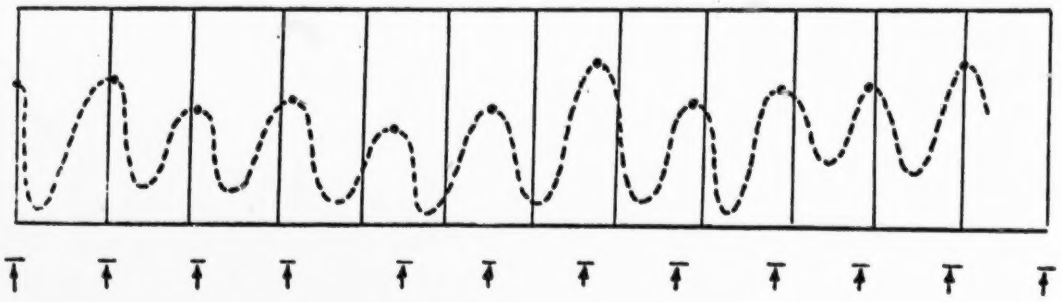
- A SPACE HAZARD -

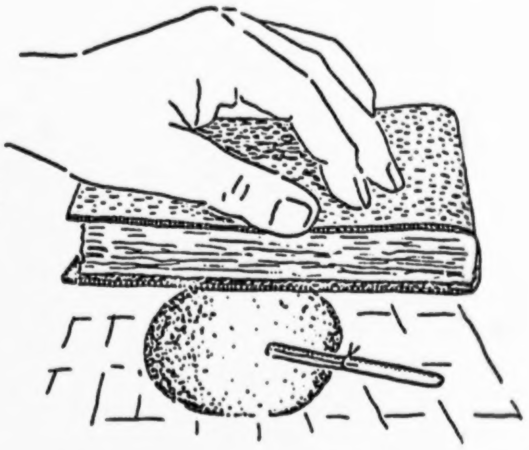


For the past two centuries, it has been known through solar observation that dark spots appear, in irregular 11-year cycles, on the sun. It is generally believed that the sun spots are the result of solar storms similar to hurricanes in the earth's atmosphere. The solar storms are caused, according to this theory, by an increase in activity on the sun due to the gravitational attraction of the planet Jupiter.

At times of great sun spot activity, there is an increase in radiant energy from the chromosphere of the sun. This radiation disrupts communications on the earth's surface, increases auroral displays, and makes the weather slightly warmer.

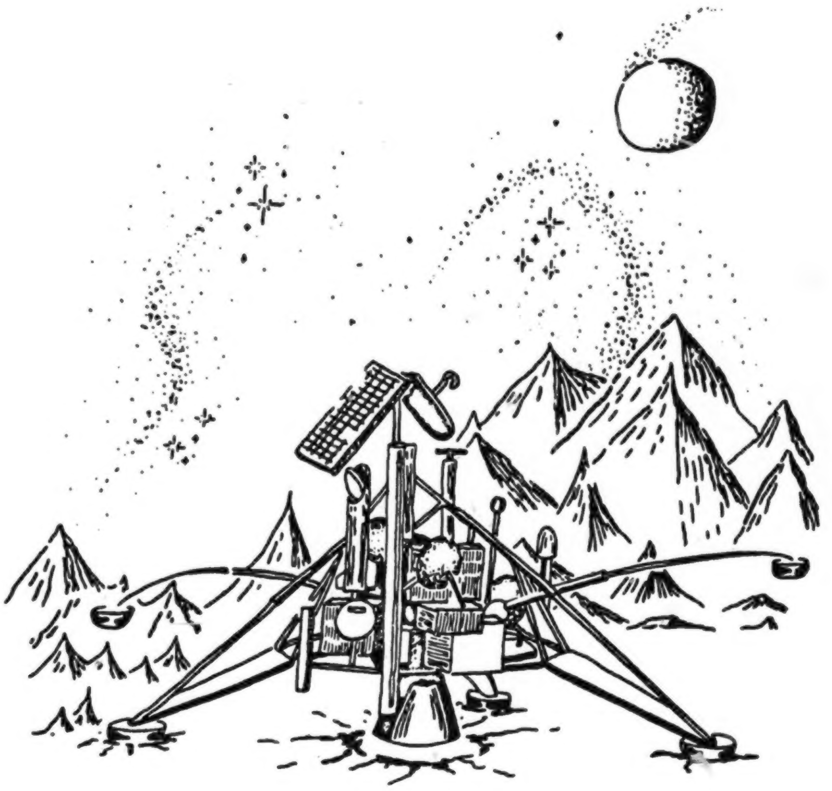
Solar radiation in the form of gamma rays is a hazard against which there is little protection for space travelers. Space scientists, therefore, are planning extended space journeys for periods of infrequent sun spot activity.





The increase in surface activity on the sun as a result of gravitational pull by the planet Jupiter is a phenomenon similar to the tides on the earth being caused by the gravitational pull of the moon. The effect produced by the tidal distortion of the sun can be shown by removing an ordinary thermometer from its wooden backing and placing it in a hole drilled to the center of a soft, sponge-rubber ball. Taking care not to break the thermometer, roll the ball by compressing it under a book for a few minutes. Notice the change in the temperature as shown on the thermometer due to the friction of the molecules of rubber upon each other.

Reference: Smith, F. Graham. Radio Astronomy. Baltimore: Penguin, 1960.

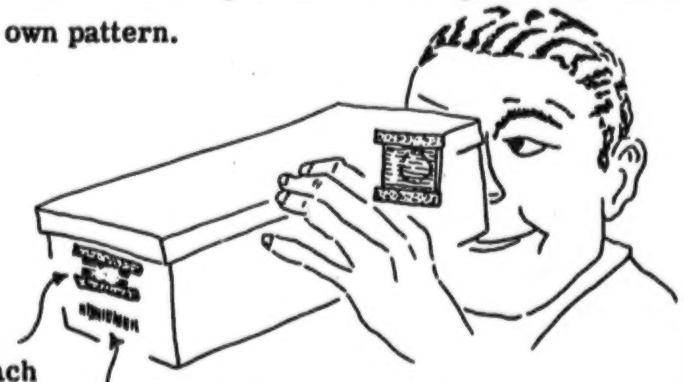


MATERIALS ANALYSIS

By using a sensitive instrument called a spectroscope, scientists have been able to analyze the composition of materials located a great distance away. The spectroscope has been used to determine the composition of the sun and other stars and of the atmosphere of many of the planets. Spacemen in the future will use this kind of device to analyze the chemical composition of their immediate surroundings.

A spectroscope passes light rays emitted by various materials through a diffraction grating, which spreads them out in a band or spectrum. Since each element shows certain characteristically bright areas in a spectrum, the material can thus be easily identified.

Make a shoe box spectroscope with a square inch of replica grating, some masking tape, and a double-edged razor blade broken in two. Arrange these items according to the illustration and suggestions. The lines on the grating should be parallel to the slit. Adjust the width of the slit until a faint, dark line appears down its middle. Look through the spectroscope at various bright gases such as neon and argon in lamps or signs. Notice the bright lines in the spectrum, which indicate that each element has its own pattern.



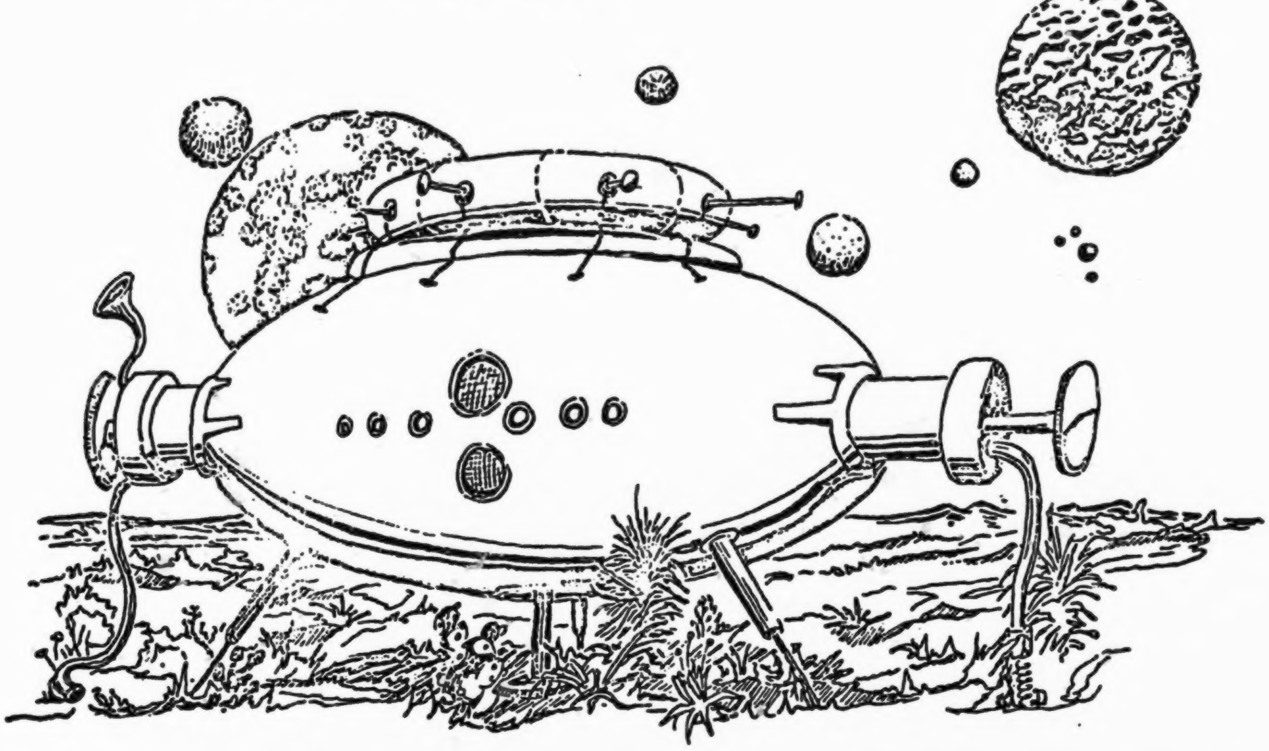
Eye hole one inch in diameter. On inside, attach a piece of "transmitting diffraction grating replica" with tape.

Spectrum seen inside box.

Edges of razor blades facing each other about the thickness of a razor blade apart. Tape over a 1 x 1/2-inch slow in the end of the box. After the grating is in place, adjustment of the slit size and position may have to be made.

Reference: Hynek, J. Allen. Challenge of the Universe. Washington: National Science Teachers Assn., National Education Assn., 1962.

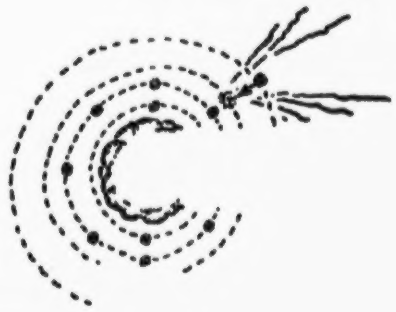
ATOMIC ACTIVATION



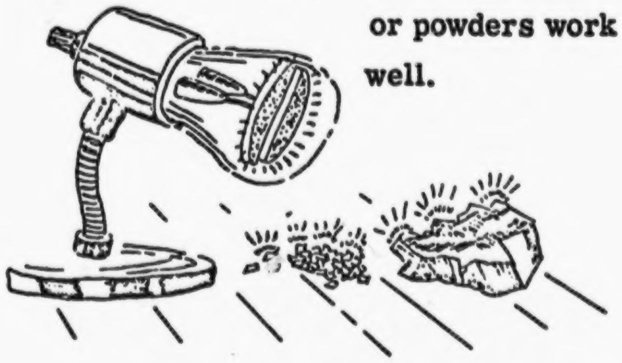
Unmanned spacecraft are being designed to travel to distant worlds, land on them, and analyze the environment. Among the instruments to be used for the latter purpose will be the neutron activator. To analyze and identify complex molecules, this instrument will bombard samples of unknown substances with neutrons and the resultant, characteristic emissions will then be compared with similar emissions from known substances.

According to theory, electrons are driven out of their normal orbits around the nucleus of the atom by the eradiated energy. They absorb radiant energy in the process and, as they swing back into their regular orbit, this energy is given off in the form of visible light.

Burn some common table salt (NaCl) by holding it in a flame on the end of a piece of bent wire. Notice the particular yellow light produced by the sodium vapor.



The phenomena of atomic activation can be demonstrated with an ultraviolet light directed, in the dark, at some fluorescent material—most soap flakes or powders work well.

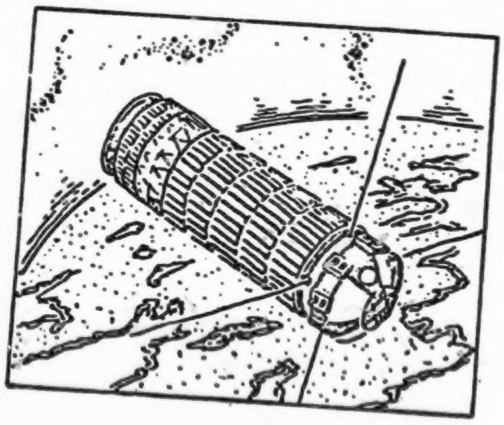


Reference: New York Times. America's Race for the Moon: The Story of Project Apollo. New York: Random House, 1962.

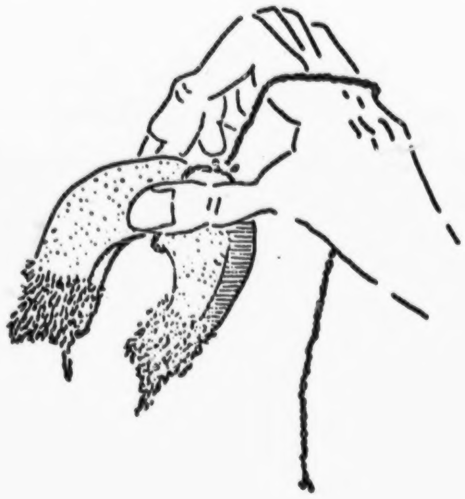
"STAR DUST"

If you look up into the sky on a clear night, you may see a few meteors or "shooting stars." These streaks of light come from the small dust- or sand-like meteoroids streaming into the atmosphere at more than 25,000 miles per hour. As the meteoroid burns, small bits separate from it and drift to the earth. On the earth, the particles can often be picked up with a magnet. It has been estimated that over 100 tons of iron nickel dust falls on the earth each day.

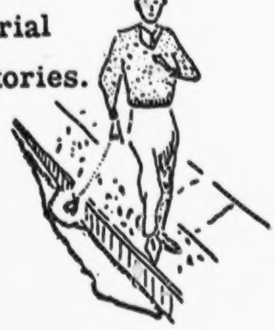
Micro-meteoroids, incidentally, are a nuisance to spacecraft. The fast-traveling bits of space-dust dent and puncture balloon-like structures and scratch and abrade the smooth surfaces and window-like areas of other craft. Space-dust is also responsible in part for slowing down satellites so that they spiral back into denser atmosphere and burn up.



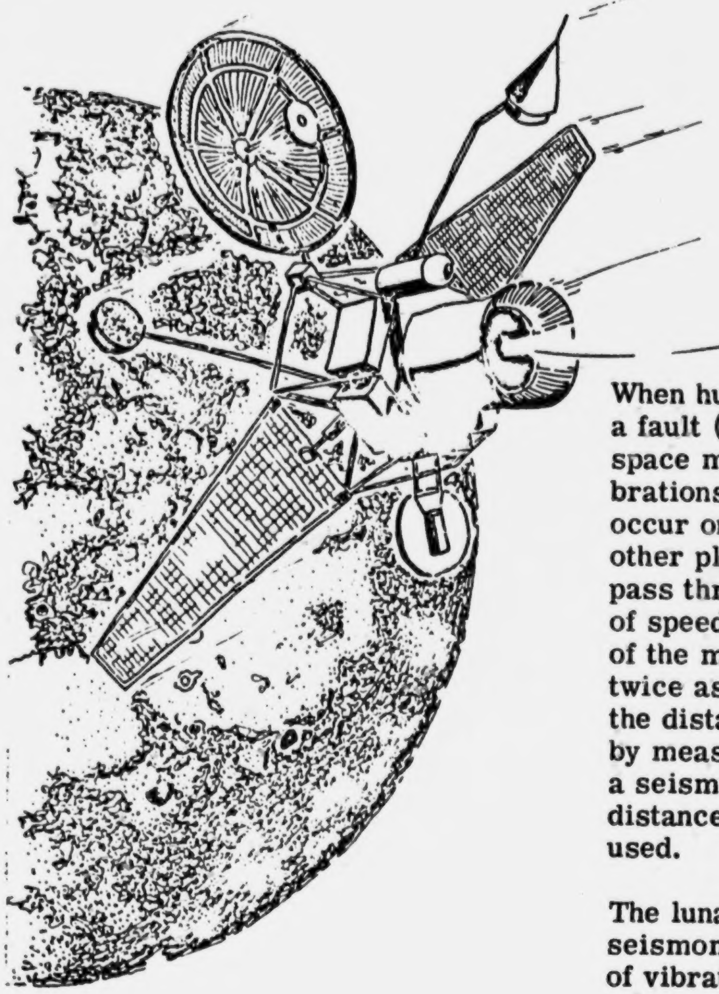
Explorer XIII, launched August 25, 1961, to obtain data on micro-meteoroids (cosmic dust).

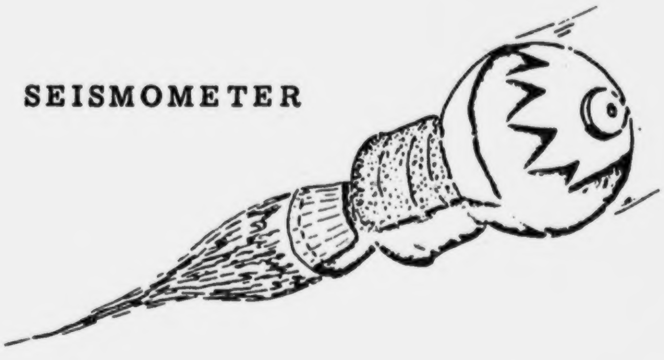


It's hard to believe that star dust sprinkles the earth. But drag a small magnet on the end of a string along a gutter where water runs. Some scientists estimate that ten percent of the material collected by the magnet will have come from outer space. The rest is probably industrial waste from factories.



Reference: Gamow, George. Biography of the Earth. New York: Mentor, 1948.



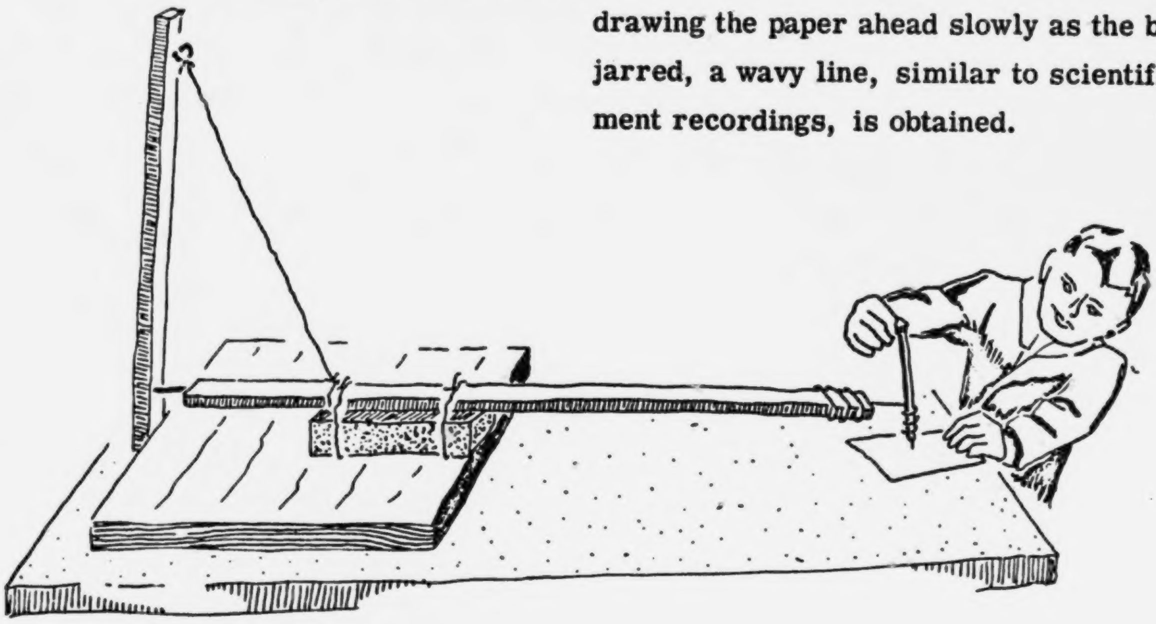


SEISMOMETER

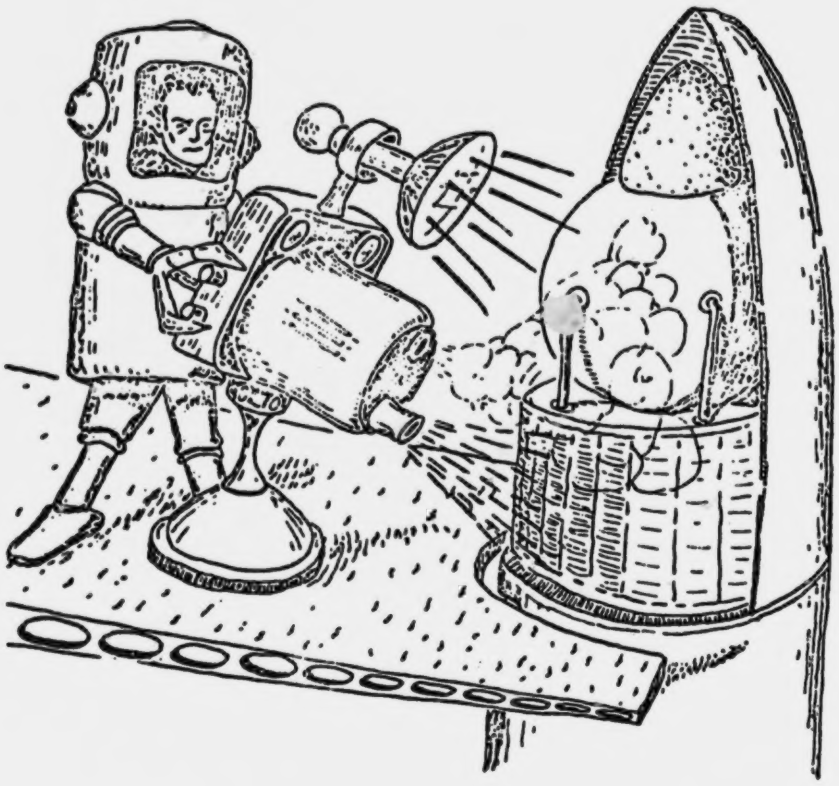
When huge blocks of rock slip past each other along a fault (a break in rock strata) or when chunks of space material come crashing down, they set off vibrations which shoot out in all directions. This may occur on the earth or on our moon, or any of the other planets. The vibrations, traveling in waves, pass through various materials at different rates of speed, depending on the elasticity and density of the material. Ordinarily, primary waves travel twice as fast as secondary waves. Calculation of the distance away of a disturbance can be figured by measuring the time between the two readings on a seismometer. To determine direction as well as distance, however, three seismometers must be used.

The lunar capsules of Ranger spacecraft carry seismometers to measure the amount and type of vibration on the moon. This information is sent back to earth by means of a small radio.

The principle on which a seismometer is based can be demonstrated with equipment as illustrated below. The weighted stick should swing sidewise quite freely so that the least jar of the table will cause the pen to make a mark on the paper. By drawing the paper ahead slowly as the base is jarred, a wavy line, similar to scientific instrument recordings, is obtained.



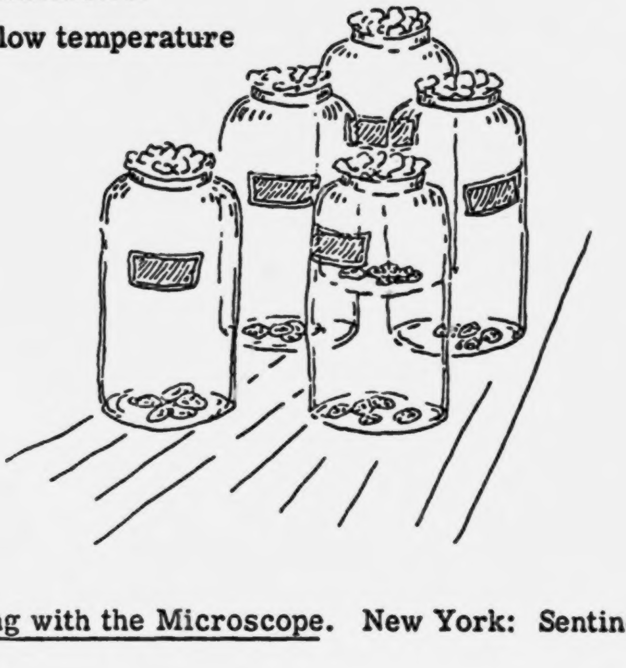
Reference: New York Times. America's Race for the Moon: The Story of Project Apollo. New York: Random House, 1962.



DECONTAMINATION

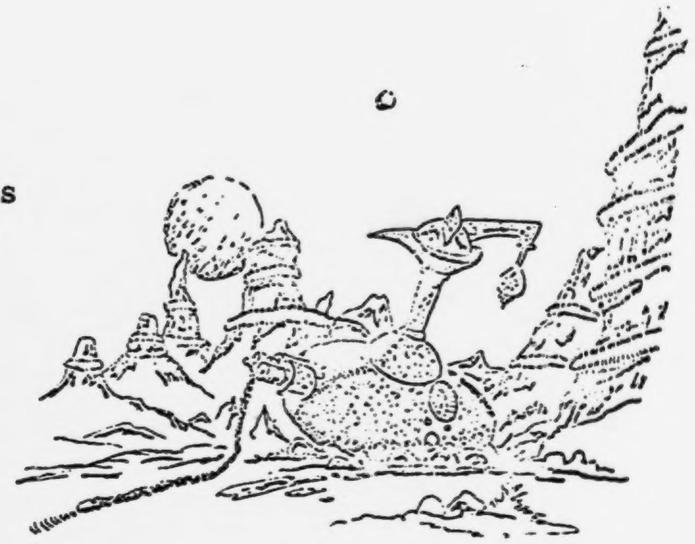
Elaborate measures are taken to keep planetary and lunar landing craft relatively clean of terrestrial contamination. This is necessary to ensure that no living forms from the earth invade the foreign environments before we have a chance to study them. These measures, used by our space scientists, include steam washes, antiseptics, and radiation.

To show the effect of these types of decontaminants, soak some ordinary dry beans in cold water for several hours. Put several beans in each of four bottles of equal size and cover with water. Add a little iodine to one, some alcohol to a second, an antiseptic such as Clorox, Lysol, or some other household cleaner to a third, and leave the fourth bottle untreated. Stopper the bottles with cotton and leave them in a warm place for several days. The foul odor of the contents will indicate activity of micro-organisms. (Note: While this gives some idea of chemical decontamination, not all micro-organisms are affected in the same way.) Also try exposing a clean bottle containing the beans to ultraviolet or other types of light and to high and low temperature conditions.



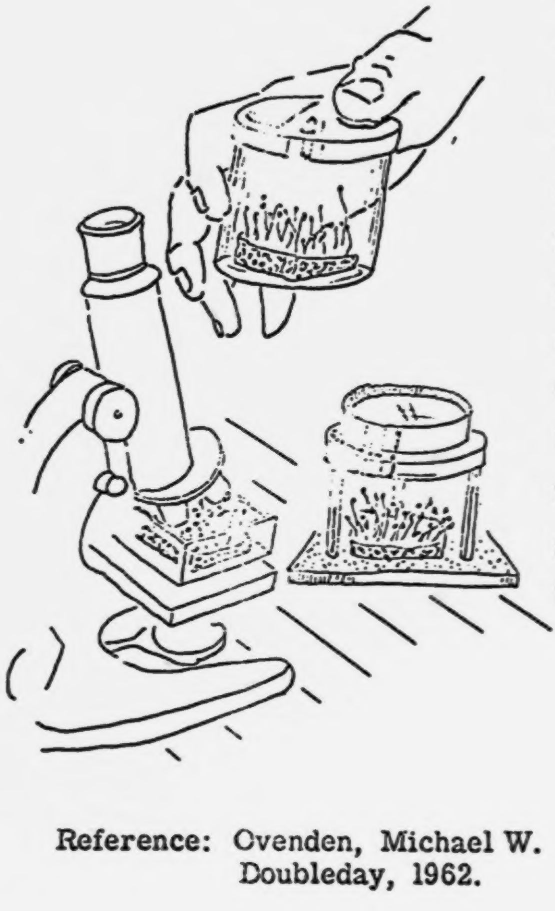
Reference: Johnson, Gaylord. Hunting with the Microscope. New York: Sentinel, 1955.

LIFE TRAP



Molds, yeasts, or similar micro-organisms can be found almost anywhere in the world. Any bit of material, whether of air, water, or earth, contains numerous examples of such micro-organisms. Under ideal conditions, they sprout into lush, spectacularly beautiful, microscopic jungles.

This simple form of life offers space scientists a means of investigating the possibility of life on other planets. The scientists believe there is a greater possibility that this type of plant life, or something comparable, would be associated with other living things. Accordingly, they have designed small robot instruments which will land on the surface of a distant planet, and with arms, long, sticky strings or pneumatic tubes draw some of the surrounding material inside and drop it into a culture medium. Periodically, this liquid food will be checked for chemical changes and the container for temperature or atmospheric composition changes. This information will be transmitted by telemetry back to the earth, where the biological scientists can compare it with already existing knowledge.



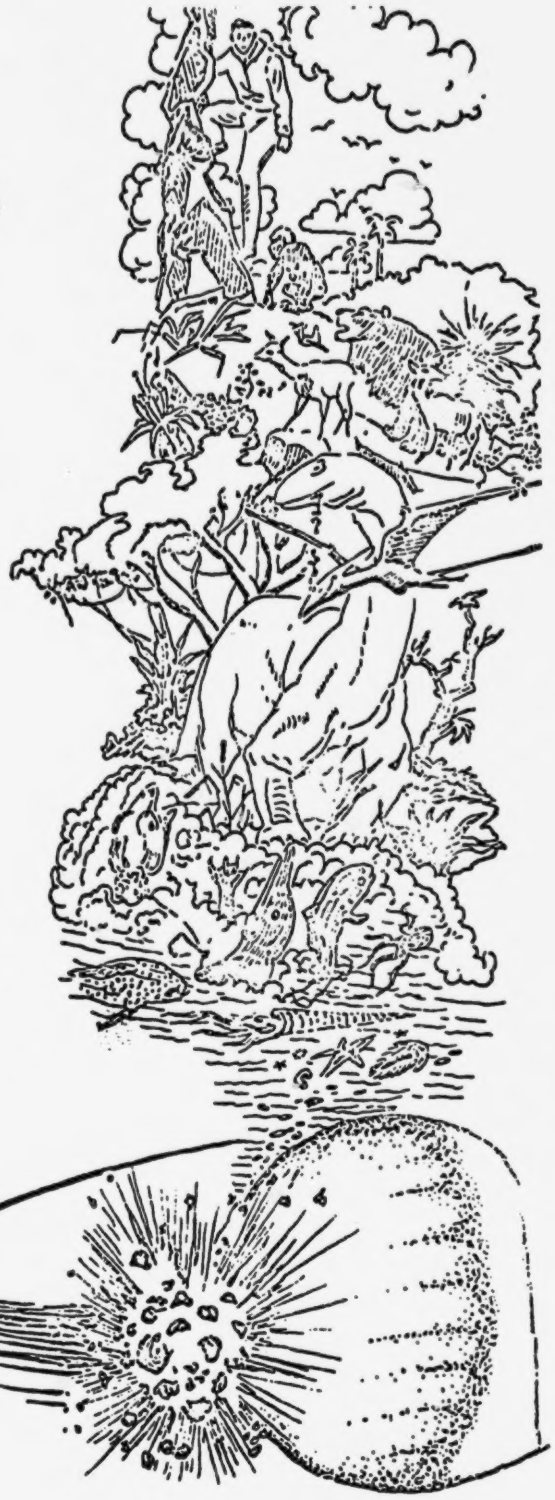
A covered refrigerator dish or clean glass jar makes a good environmental area for some types of microorganism growth. Obtain a supply of molds by rubbing a piece of bread across a carpet or other floor area. Moisten the bread and put it into a covered environmental area for several days. Since molds and related plants do not possess chlorophyll, they flourish without sunlight. Examine the growth with a low powered microscope or hand lens. Viewing is best with a bright light falling on the surface of the growth. Notice the rate of growth and the different types, as well as changes in the base materials.

Reference: Ovenden, Michael W. Life in the Universe. Garden City, N. Y.: Doubleday, 1962.

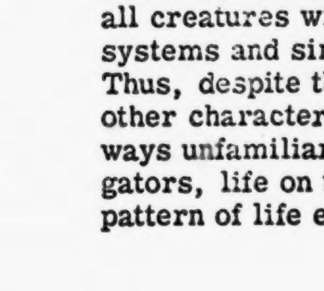
INTERSTELLAR PASSENGER CAPSULES

Scientific evidence indicates that interstellar travel has been a commonplace since the beginning of time. Used on the flights are passenger capsules which are solidly built and well protected against the hazards of space and the dangers of entry into alien atmospheres. To survive the long years of the journeys, the passengers apparently resort to the technique of suspended animation.

Obviously these passengers are not human or even remotely human or intelligent creatures. They are basic, complex, protein molecules, such as DNA (Desoxyrybonucleic Acid), carried by microorganisms trapped in the structure of stoney meteorites. Many familiar bacteria and certain protozoa and algae would make ideal space travelers because they are able to survive enormous gravities from acceleration, high intensities of radiation, exposure to an atmospheric vacuum, and eons of time. Upon entering any environment with water, minerals, methane, ammonia, and life-zone temperatures, all creatures with the same fundamental protein systems and similar biochemistry can evolve. Thus, despite the fact that physical shapes and other characteristics would probably evolve in ways unfamiliar as yet to earth-bound investigators, life on the earth may indicate the pattern of life elsewhere in the universe.



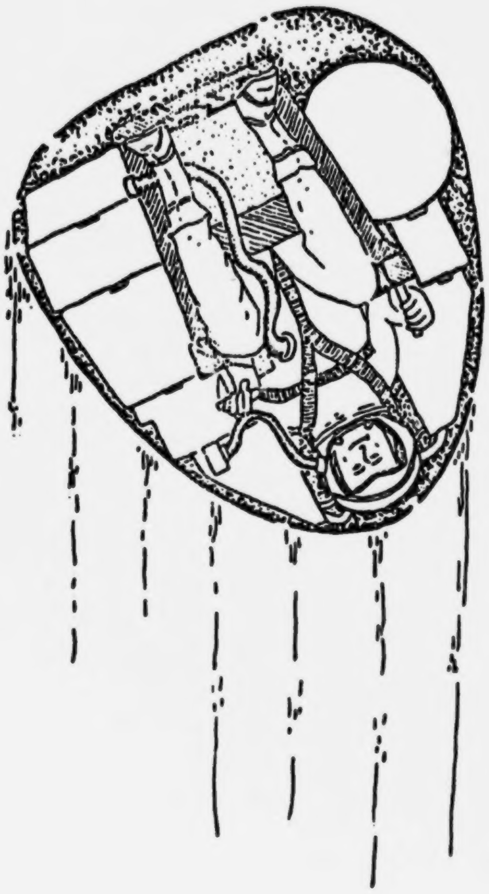
Put some pond water into a glass jar and add a few dried leaves, some hay, or a few oats. (A bit of raw liver makes an excellent addition, but it must be removed after a day or two because it develops an unpleasant odor.) Bacteria feed on the organic matter and greatly increase in number. By using a small, 10-power magnifier for observation, notice the rate in which the protozoa multiply as they feed on the bacteria.



Note: Small gauze nets can be used to trap the fast-moving creatures for observation.

Reference: Simon, Harold J. Microbes and Men. Washington, D. C.: National Science Teachers Assn., National Education Assn., 1963.

HUMAN FACTORS IN BIOASTRONAUTICS

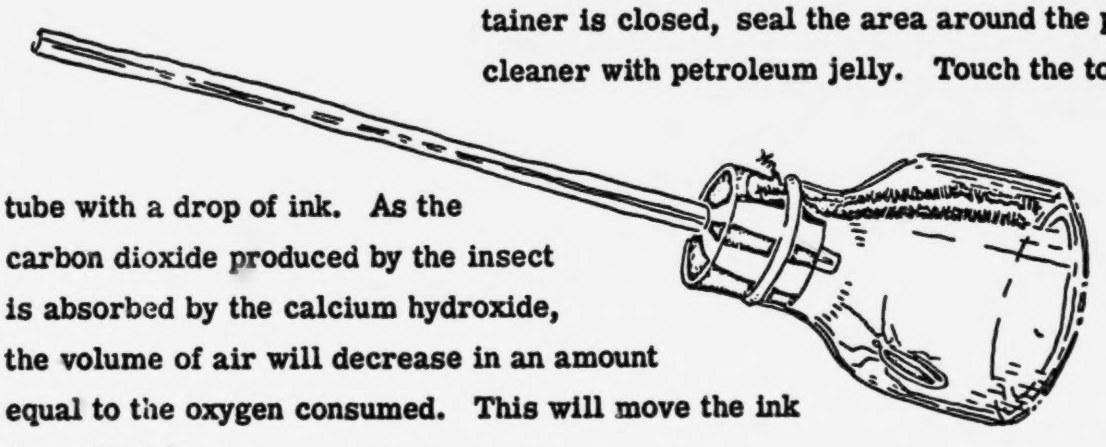


Man is the most complex of all instruments. He can exist only in the relatively limited environment which answers his physiological needs and tolerances.

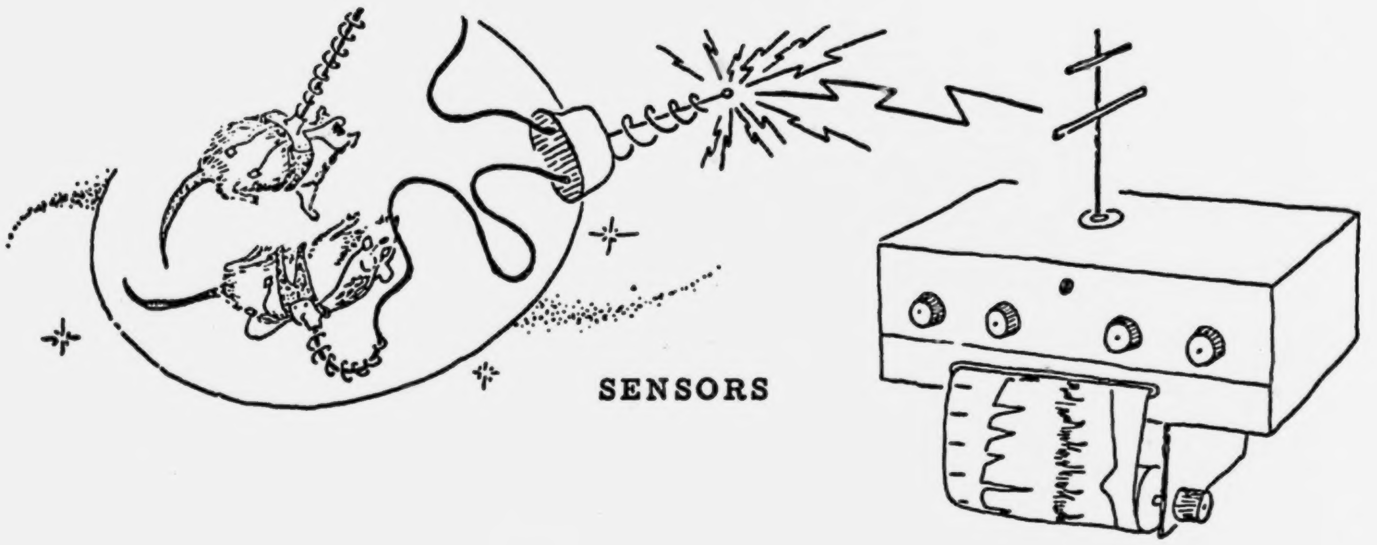
Man's needs and tolerances include the following: .25 to 4 atmospheres of pressure, depending on the gas mixture; 0 to 100 percent relative humidity; 0 to 35 Gs of positive acceleration and 0 to 12 Gs of negative acceleration; 0 to 130 decibels of sound; 1500 to 2500 milliliters of water; and about 2000 calories of food per day.

In designing manned spacecraft, therefore, scientists must devote intense and continuous research and development into life support systems. Oxygen consumption is only one example. For this phase of the research, the oxygen consumption of small animals in sealed containers has been correlated directly with that of astronauts in manned spacecraft in outer space.

For your own research into oxygen consumption to sustain life, put an insect such as a grasshopper or cockroach into a pint glass container. Dip two pipe cleaners in a saturated solution of lime water (calcium hydroxide) and hold them in place with a one-holed rubber stopper which has been fitted with a capillary (small bore) glass tube. When the container is closed, seal the area around the pipe cleaner with petroleum jelly. Touch the top of the tube with a drop of ink. As the carbon dioxide produced by the insect is absorbed by the calcium hydroxide, the volume of air will decrease in an amount equal to the oxygen consumed. This will move the ink down the tube.



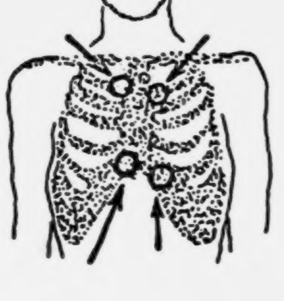
Reference: Benson, Otis O., Jr., and Hubertus Strughold, editors. Physics and Medicine of the Atmosphere and Space. New York: Wiley, 1960.

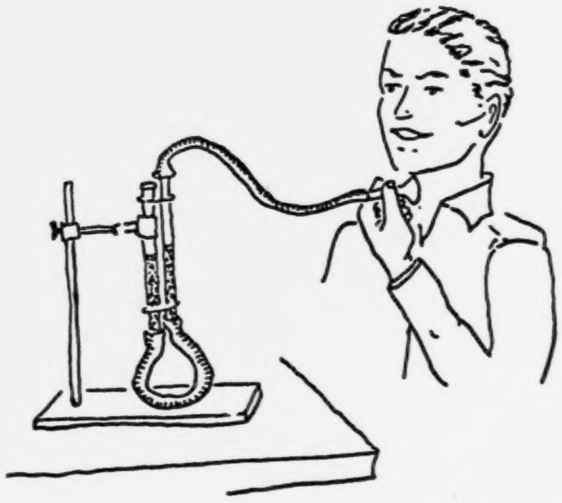


SENSORS

Among the vital functions of any space shot is the gathering and transmittal of data, through telemetry, on the physiological performance of laboratory animals or of the astronauts themselves while they are in flight. The data are picked up by a number of sensors, attached to the body, which—as the term implies—sense or "observe" body reactions. These observations are passed to on-board electronic equipment, which in turn transmits them by radio waves to a distant receiving station, where they are interpreted and recorded.

For an idea of the way the body affects a sensor, half fill a manometer tube, i.e., a U-tube made from two pieces of glass tubing and a short length of rubber tubing, with water. Attach a length of rubber or plastic tubing which has about a two-inch funnel on the end. Press the funnel over the carotid artery in your neck, beside the windpipe, or over your heart on the left side of the chest. Observe the liquid in the tube as it pulsates with your heartbeat.

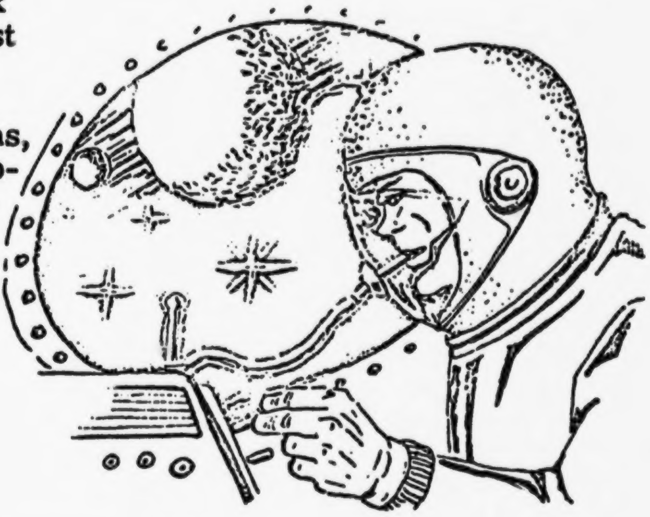




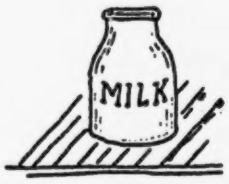
Reference: Kinney, William A. Medical Science and Space Travel. New York: Watts, 1959.

SPACE FOODS

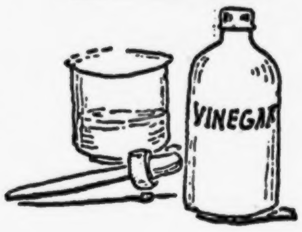
Nutrition experts and scientists specializing in space medicine have been working at the task of developing the concentrated food which best meets the nutritional needs of astronauts in space. In this work, they have tried tubes filled with pastes and liquids, survival rations, wafers, food pills, and concentrated food capsules. Thus far, none of these concentrates have met every requirement.



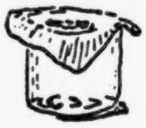
In their research, the scientists first established minimum requirements for survival; they concluded that the average human requires about 2000 calories of food. Fifty-two percent of the amount should be carbohydrates; 13 percent, fat; and 15 percent, protein.



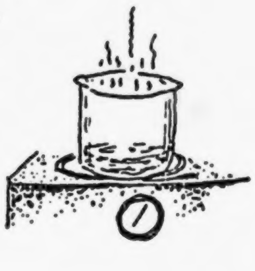
Milk is a good example of a food which contains fat, protein, and carbohydrates (sugars) in about the required portions. A series of steps will show that milk is made up of these component parts. First, allow a pint bottle of raw milk to stand in a refrigerator until the cream, containing all the fat, rises to the top. Pour off the cream into another bottle and let the second bottle stand at room temperature. After several days, shake it vigorously. The butter obtained is about four-fifths fat and contains the fat soluble vitamins.



Second, heat the skimmed milk until it is lukewarm and stir in white vinegar a few drops at a time. When the milk is then filtered through a cloth, curds which are a kind of protein called casein will remain.



Third, boil the remaining liquid, that is, the whey, for a few minutes. Milk albumin, another kind of protein, can be separated by filtering the liquid through paper toweling.



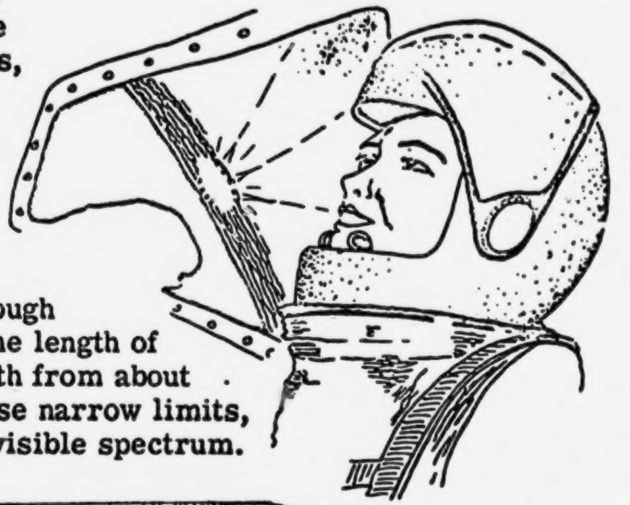
Finally, evaporate the remaining liquid in a double boiler. Milk sugar, a carbohydrate, and minerals and water soluble vitamins remain.

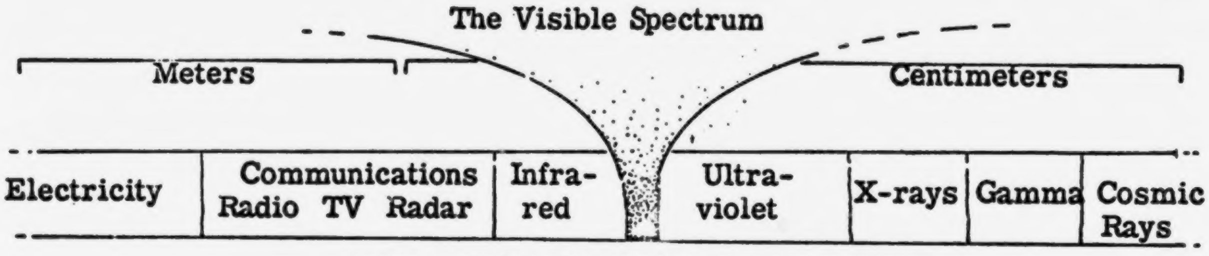
Reference: Gaul, Albro. The Complete Book of Space Travel. New York: World, 1956.

HUMAN COLOR SENSITIVITY

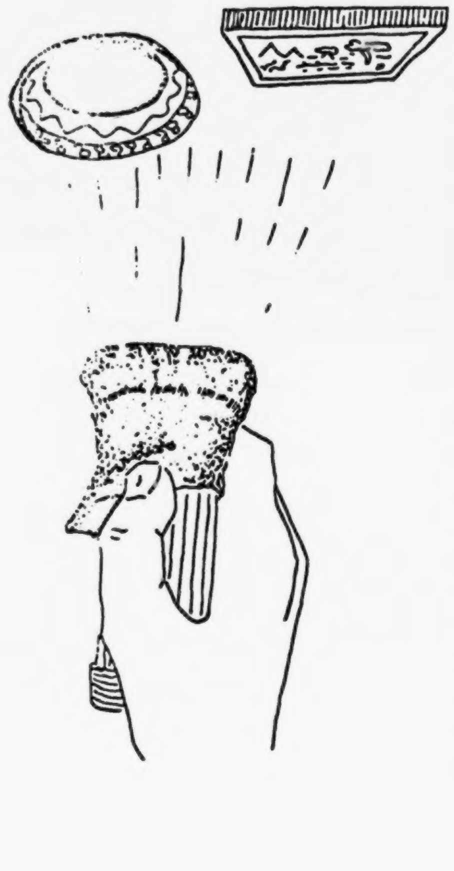
Human beings have difficulty in determining the color of distant objects because the sensitivity of the human eye to color is not always the same. When illumination dims, color sensitivity shifts from the red to the violet end of the visible spectrum. (These facts pose special difficulties to astronauts, astronomers, and other persons whose work involves accurate observation of great distances.) The shift in color sensitivity is especially noticeable at twilight, when the colors of even familiar objects seem to change.

Man sees colors that vary from violet through green and yellow to red, depending upon the length of the electromagnetic waves ranging in length from about .00004 to .00007 centimeters. Within these narrow limits, man finds all of the light and color of the visible spectrum.





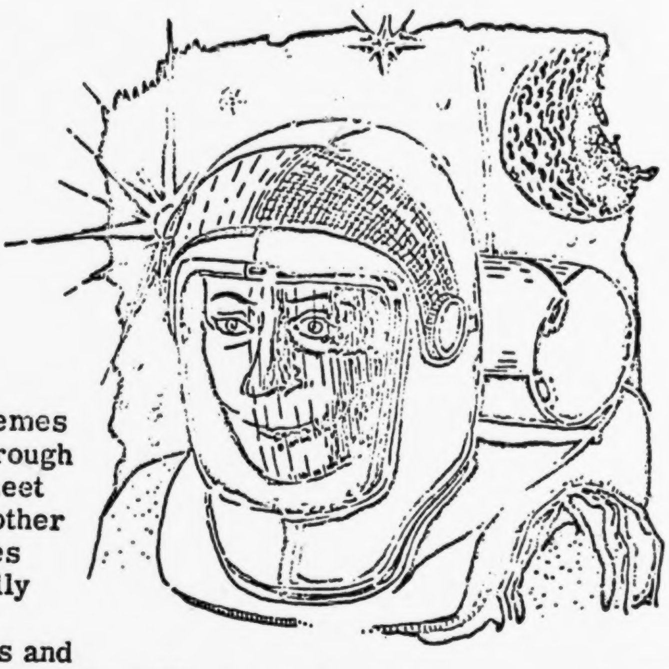
THE ELECTROMAGNETIC SPECTRUM



Beyond the visible spectrum, ultraviolet waves, x-rays, gamma rays, and cosmic rays are on the short wave length and infrared (heat) waves, radio, and electrical waves are on the long wave-length end.

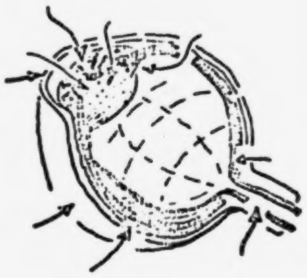
To experience the way color shifts with light intensity, cover a flashlight with sufficient layers of tissue paper so that objects can be barely seen by its light in a dark room. Look at colored pictures and notice that the blue and green colors seem to be relatively bright while the red and yellow colors seem quite dim. As the light intensity is gradually increased, the situation reverses and the red and yellow colors assume the greatest brightness. This phenomenon is called the Purkinje Effect, named for the Czech physiologist who first described it.

EYES AND SPACE LIGHT



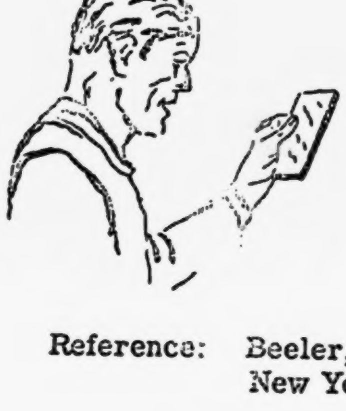
Astronauts are subjected to extremes of visible light when traveling through space. Undoubtedly, they will meet the same extremes in exploring other worlds. Their eyes, like the eyes of all humans, adjust automatically to ordinary changes in light intensity, but for intense brightness and sheer blackness mechanical means such as filters and illuminators, must be used to aid them in seeing.

The various parts of the eye act either to protect it or to record visual images. The transparent tissue of the cornea serves as an outer coat for the eyeball, covering the iris and the pupil. Tear glands supply water to wash away dust and other foreign matter. The eyelids can instantly cover the eye or uncover it.



The iris is the doughnut - shaped screen of muscle which regulates the amount of light entering the eye by adjusting the opening or pupil at its center. The lens focuses light rays on the retina, whose two different types of nerve cells are sensitive to shades of light. Finally, the optic nerve connects the eye to the brain, where the meaning of images thus reflected is interpreted.

To see how the size of the pupils of the eyes are affected by dark and light, close your eyes and cover them with your hands for one minute. When you open your eyes, quickly look at a mirror and observe the pupils change in size. Notice how the iris controls the size of the pupil, and thus of the amount of light entering the eye, by enlarging toward the center or folding up on itself toward the outside. Through the use of filters of various colors and densities, the pupil can retain its normal size regardless of the brightness of the light. Look at a bright light bulb through pieces of cellophane of different colors. Notice that some color combinations and densities allow easier reading of the words on the bulb than do others.



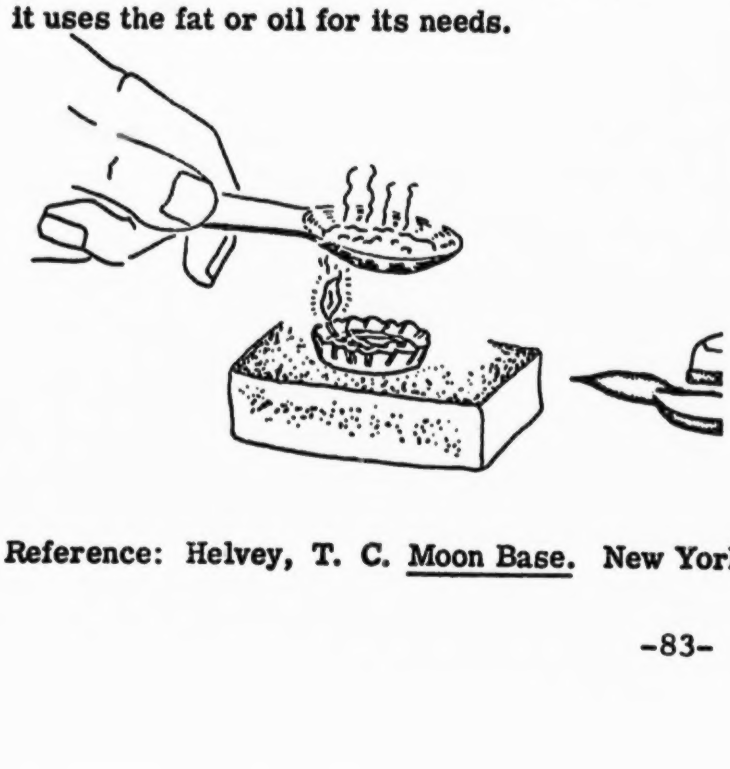
Reference: Beeler, Nelson F. and Franklyn M. Branley. *Experiments with Light.* New York: Crowell, 1958.

HUMAN ENERGY

WASTE HEAT

When sealed shut, space suits need some type of cooling system to counteract the heat given off by the astronaut's body. Under normal conditions, the human body produces heat energy at about the same rate as a 100-watt electric light bulb.

Heat energy is released by the human body through the combustion of such food materials as cooking oil, olive oil, or fat from meat or butter. To experience the heat producing properties of fat or oil, place a small amount of either in a clean soda bottle cap and place the cap on something which is fireproof, such as a brick or a stone. Add a small piece of string as a wick, and ignite. A few drops of water in a spoon will be easily boiled away when held in the spoon. An equal amount of heat energy is released by the body when it uses the fat or oil for its needs.



Reference: Helvey, T. C. Moon Base. New York: Rider, 1960.

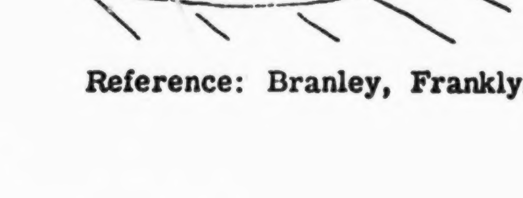
RESEARCH WITH PHOTOSYNTHESIS

Because of photosynthesis, the food-building process which takes place in plants, oxygen in the air surrounding the earth is never depleted. In photosynthesis, green leaves, using sunlight for energy, take in carbon dioxide (CO_2) from the atmosphere and water (H_2O) from the soil and turn them into carbohydrates. In this process, some oxygen is always left over. This is released by the plants into the surrounding air.

Space scientists are presently trying to develop a man-operated device which will duplicate photosynthesis in plants. When they succeed, extraterrestrial travelers will not have to transfer plant colonies by spaceship to the foreign environments.

$$\overset{\text{SUNLIGHT}}{CO_2 + H_2O} \longrightarrow (CH_2O)^x + O_2\uparrow$$

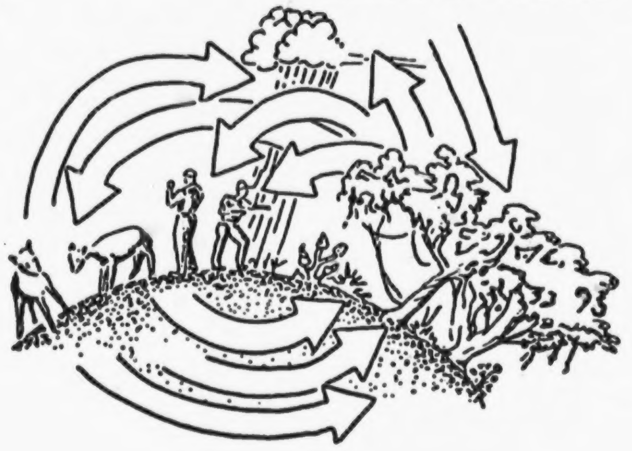
To show that photosynthesis throws off left-over oxygen, place a glass funnel over some growing water plants in a glass jar. Fill a test tube with water and invert it over the stem of the funnel without allowing any air to enter.
After several days, the test tube will contain gas.
Carefully remove the test tube and immediately thrust a smoldering broom straw or glowing wooden splinter into it. Note the action.

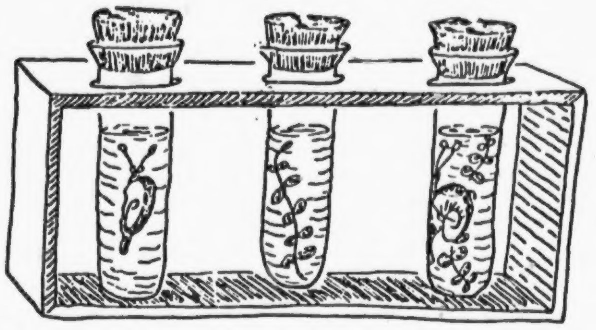


Reference: Branley, Franklyn M. Solar Energy. New York: Crowell, 1957.

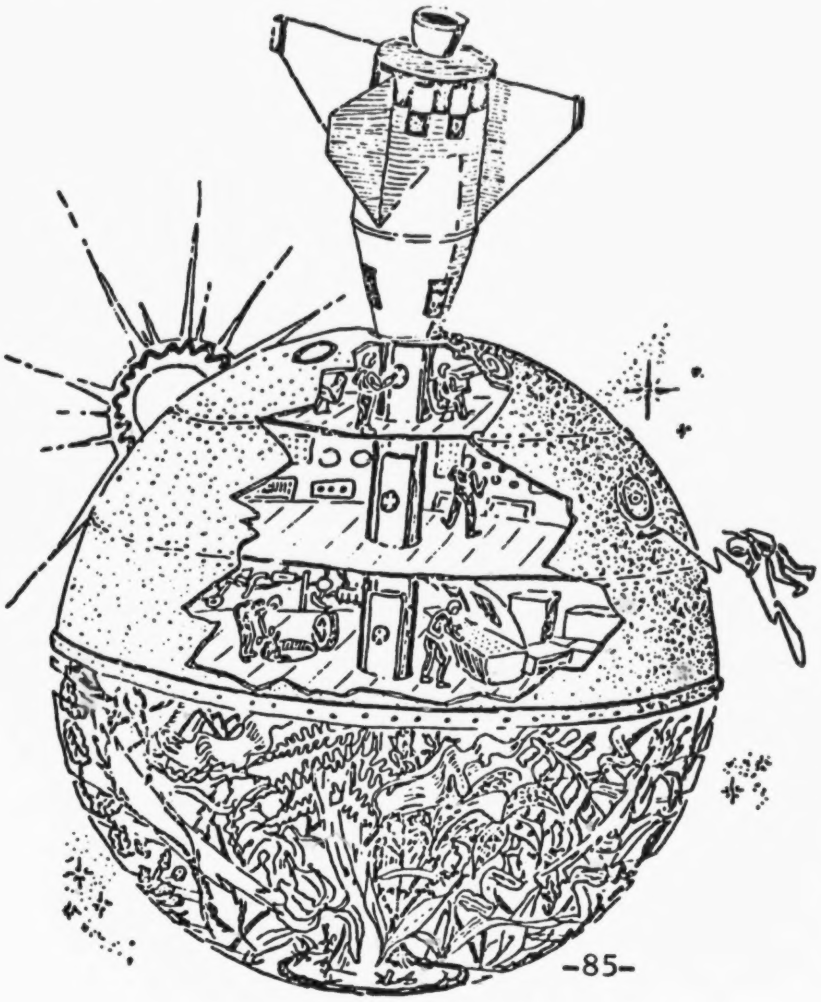
Manned spacecraft of the future may carry a life support system which duplicates to a great extent the balance in nature, i.e., the interdependence of all living things upon each other. Through research with many plants, space scientists hope to single out one which will be most suitable for establishing a balance between the animal and plant life aboard a space vehicle.

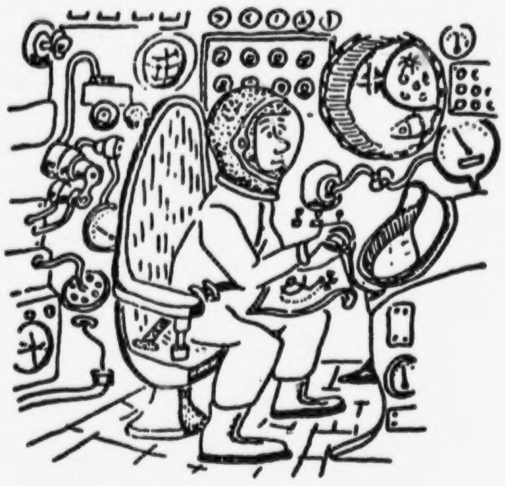
SPACECRAFT ECOLOGY





Place an aquarium snail in a test tube three-quarters full of water and seal the tube with a stopper. In another, similar test tube, place a piece of aquarium plant. In a third, place a snail and a piece of plant. Notice in which environment life can continue for the longest period.





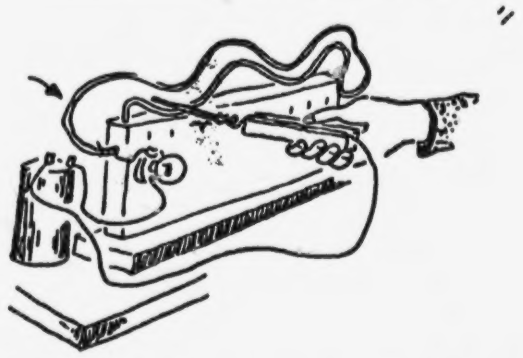
SPACE PILOT TESTS

Before he is considered for the space program, a would-be recruit undergoes tests designed to expose physical limitations which would handicap him as a pilot of spacecraft.

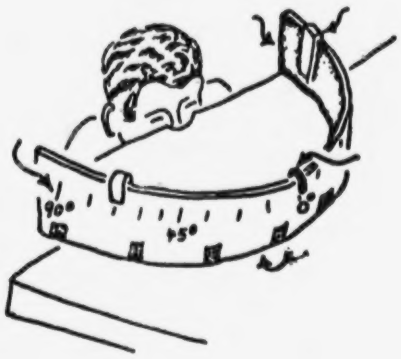
These tests include:

THE HAND-STEADINESS TEST

The hand-steadiness test provides a quick but not necessarily conclusive gauge of hand-control ability. Here, the stylus must be held in a steady grip to keep it from touching the wire and making the light flash.



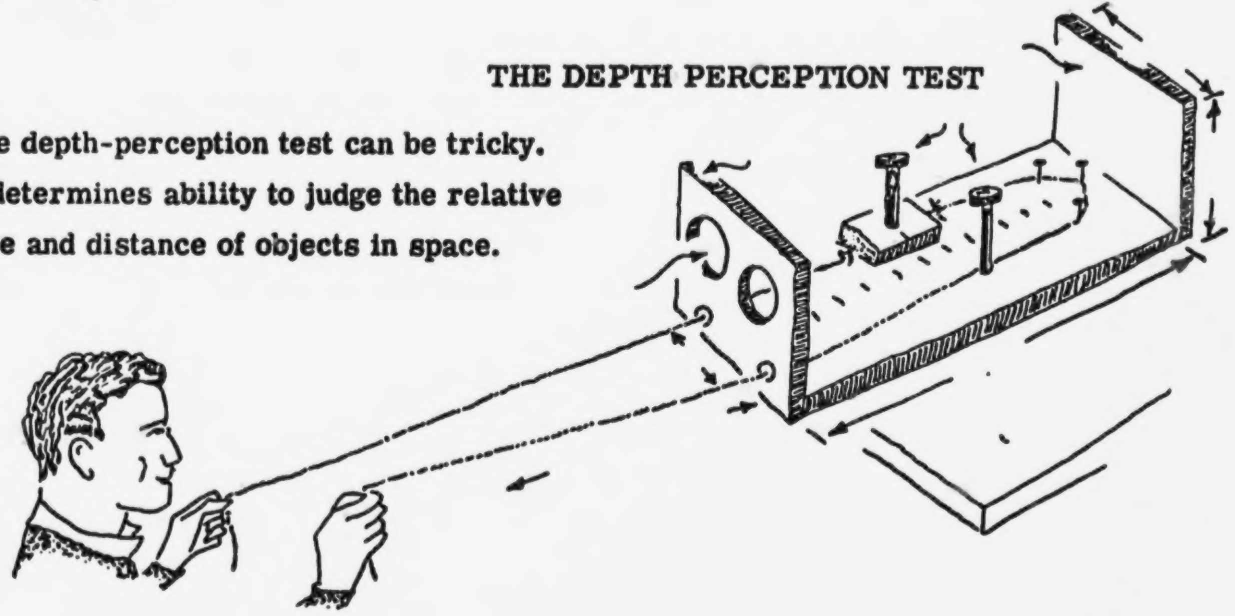
THE FIELD-OF-VISION TEST



The field-of-vision test measures vision range to the right and to the left when the eyes are focused straight ahead.

THE DEPTH PERCEPTION TEST

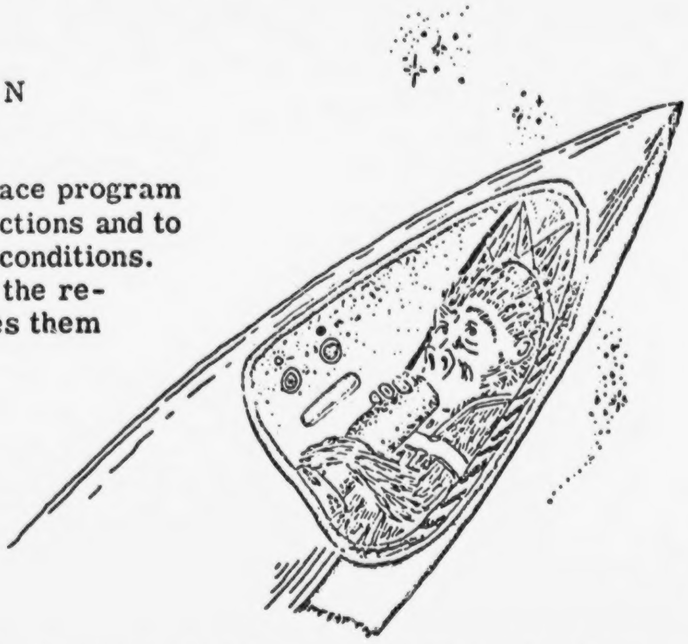
The depth-perception test can be tricky. It determines ability to judge the relative size and distance of objects in space.



Reference: Adams, Carsbie C. and Wernher von Braun. Careers in Astronautics Rocketry. New York: McGraw-Hill, 1962.

HABIT FORMATION

Laboratory animals used in the space program are trained to perform certain functions and to react in certain ways under given conditions. Repetition of the performance and the reaction, over and over again, makes them automatic. They become habits.

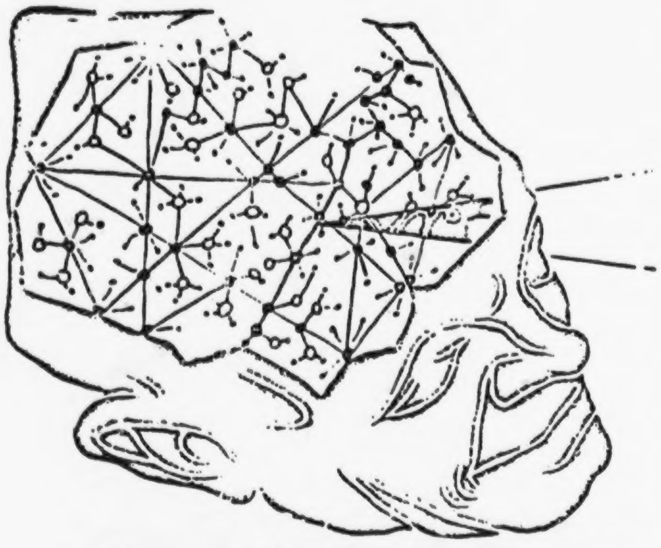


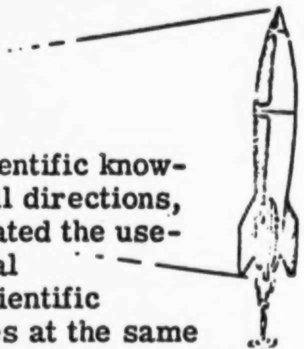
Habit formation by repetition can be demonstrated by writing with the hand not ordinarily used for that purpose. In a few days of repeated effort, either hand can be used. Try this when throwing a ball or holding a fork. In a different kind of test, demonstrate the same principle by repeated attempts to read an upside-down page.

A simple measurement of the effect of repetition can be had by writing a series of five-digit numbers which have been presented backwards. Note the time it takes to complete ten such numbers. After a five-minute practice, repeat and note the time it then takes.

Reference: N. Y. State Education Department, Bureau of Secondary Curriculum Development. Biology Handbook. Albany: N. Y. State Education Department, 1960.

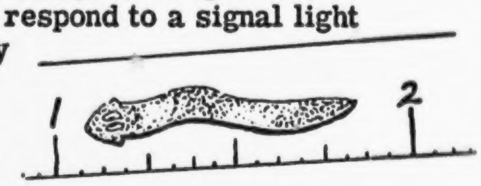
THE MEMORY MOLECULE





The explosion of scientific knowledge, bursting in all directions, has virtually eliminated the usefulness of the general scientist. If new scientific information continues at the same rate, a scientist of the future could spend his lifetime gaining a basic understanding of just one scientific field. The effort ot keep abreast with already discovered knowledge would leave little time for further research and work a real hardship on new scientific areas. Research in the processes of storing information by the human nervous system and of sharpening human memory is, therefore, highly important to the world of tomorrow.

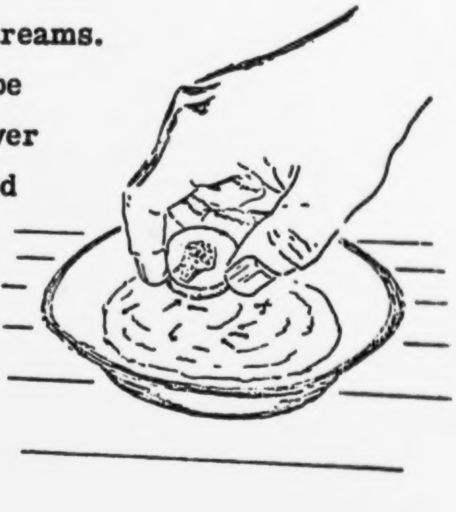
Research has already shown us that a chemical, called RNA or ribonucleic acid, found in the nervous system is made up of long, chain-like molecules which can re-arrange themselves in infinite patterns. Presumably, it is through these countless re-arrangements that the nervous system can code and store all information accepted by the body. The most promising data about RNA has come from experiments with half-inch pond worms. These crosseyed, simple-brained, flat worms, called planaria, can be trained to respond to a signal light and to run a simple maze. They have the natural ability to regenerate whole, individual worms from pieces cut from themselves and they tend to be cannibalistic.



Experiments have shown that these trainable worms, when cut in half, pass on to each half some of the learning they had mastered when whole. Also, a trained worm who becomes a meal for an untrained worm passes on what he knows to the cannibal.

In tests to determine whether RNA is really the memory molecule, tails of planaria were placed in a weak solution of the enzime ribonuclease, which destroys RNA. After heads had been regenerated to the tails, the newly created worms were found to have amnesia—they remembered nothing. Other tails placed in ordinary pond water passed on acquired information to the new heads.

Planaria can be found in stagnant ponds or slow moving streams. Because of their characteristics, many experiments can be devised with them. They will collect on a piece of raw liver placed in suitable water for a few hours. Put the collected planaria in a shallow bowl with some pond water, feed with bits of liver, and change the water regularly. Cut one in half and observe daily for a few weeks. A hand lens or low-powered microscope aids in working with or observing these creatures.



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